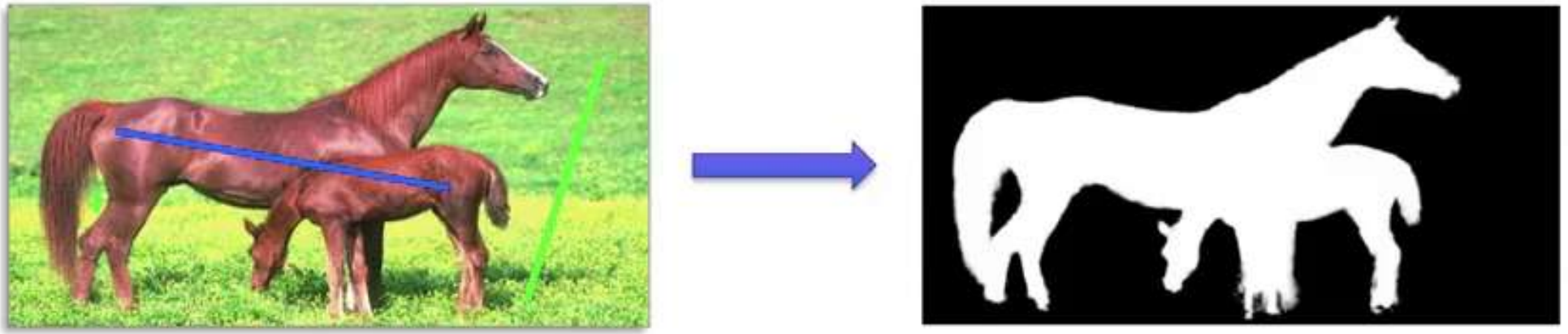
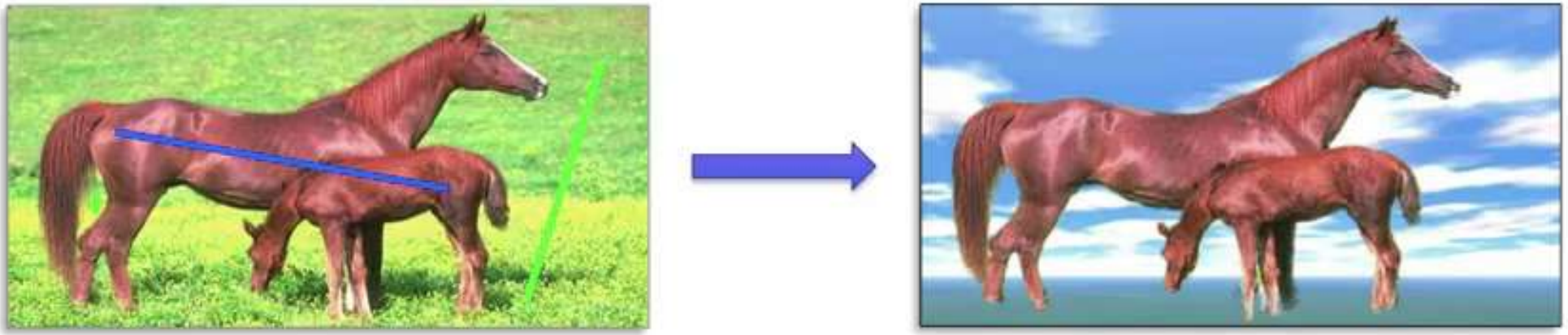
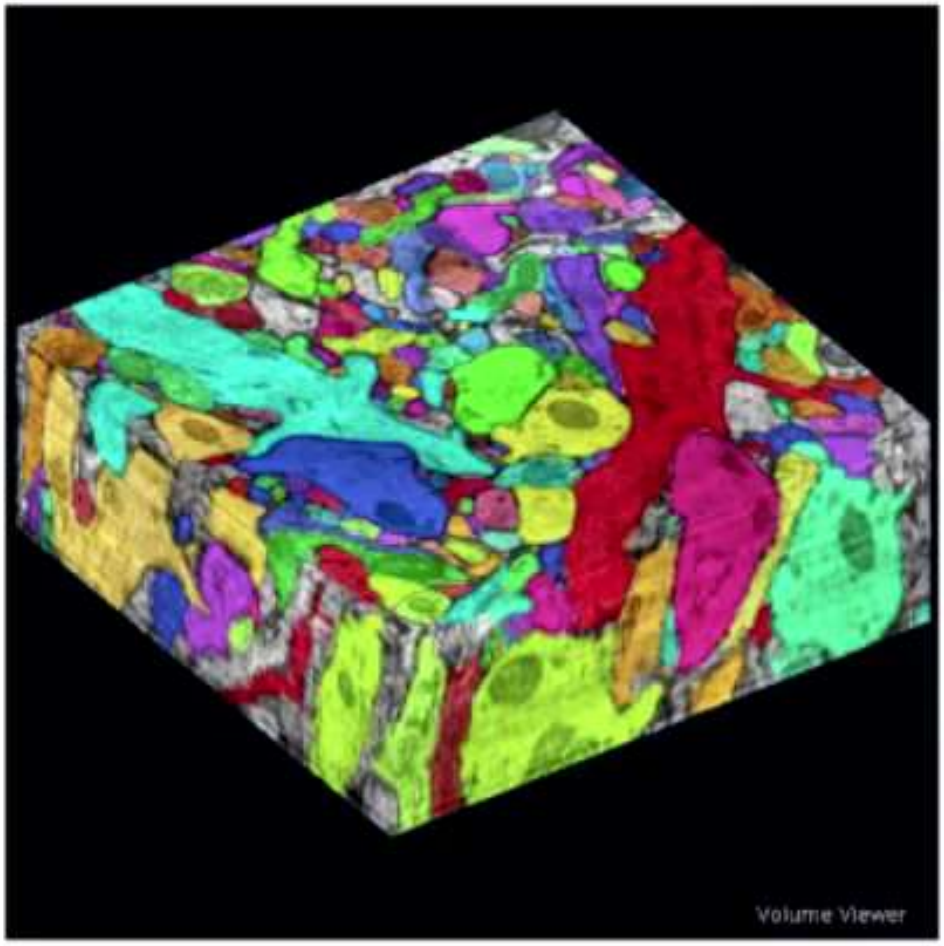
Courtesy of IEEE and IJCV



Courtesy of IEEE and IJCV



Courtesy of IEEE and IJCV



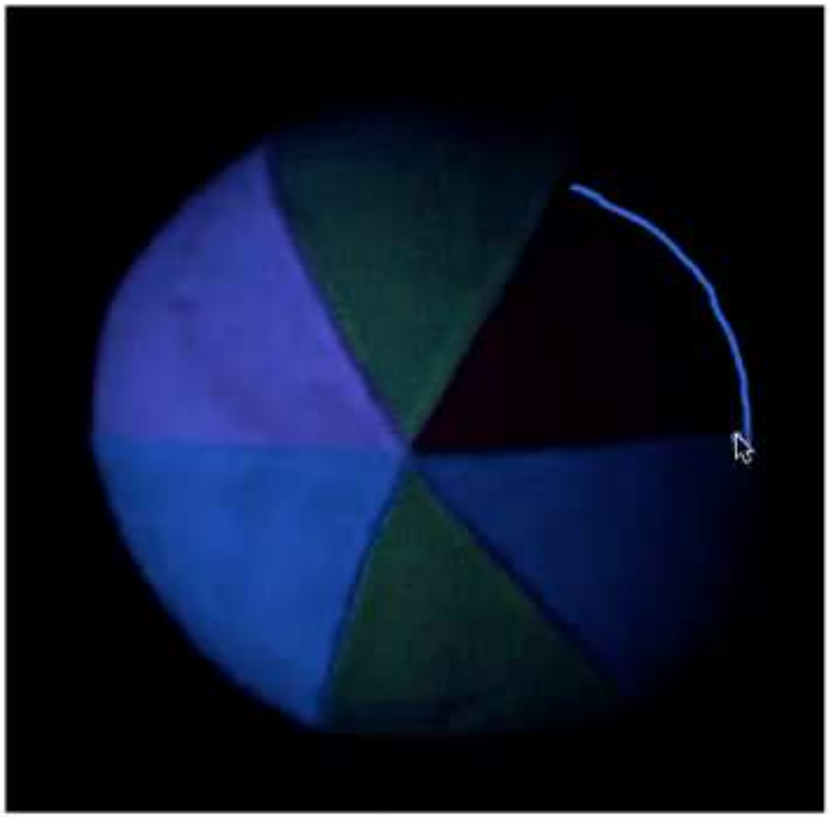
Courtesy of openconnectomeproject.org

Original SIGGRAPH project videos courtesy of Artbeats (www.artbeats.com), Mike Wilbur, Jon Goldman, and Jiawen Chen

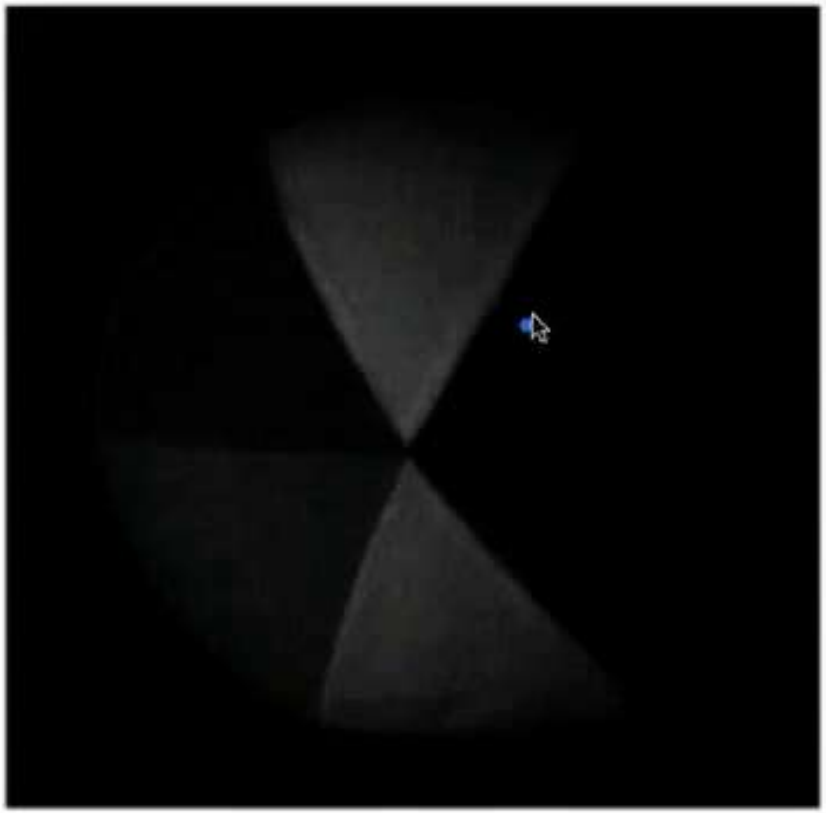
$$\nabla I = \left\langle \frac{\partial I}{\partial x}, \frac{\partial I}{\partial y} \right\rangle$$

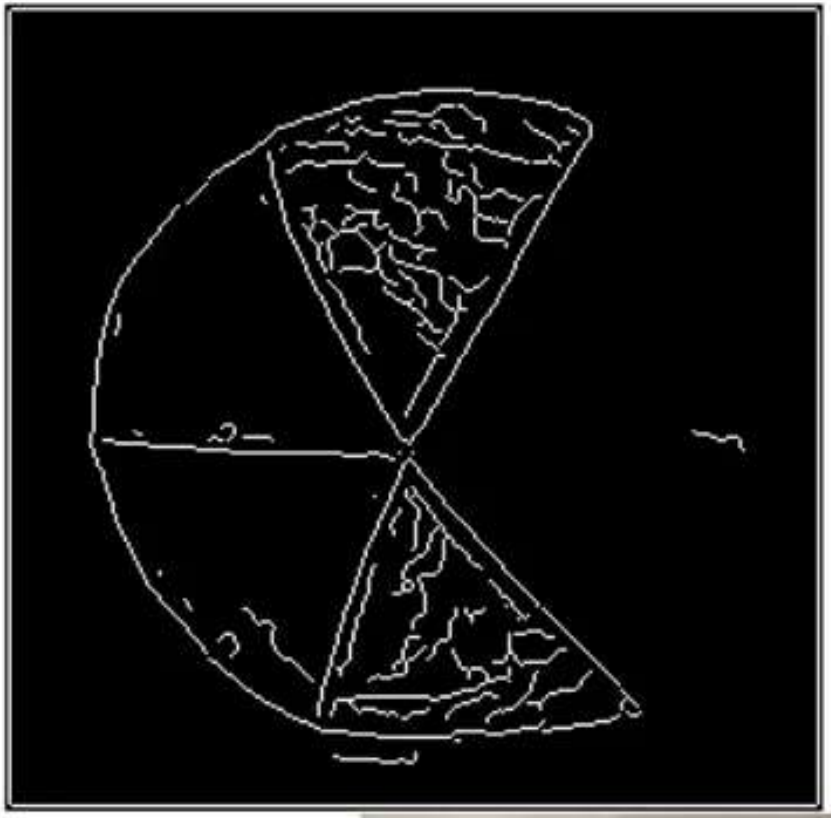
-1	+1	-1

Images courtesy of ipol.im



Images courtesy of ipol.im





Digital Image Processing, 3rd ed.

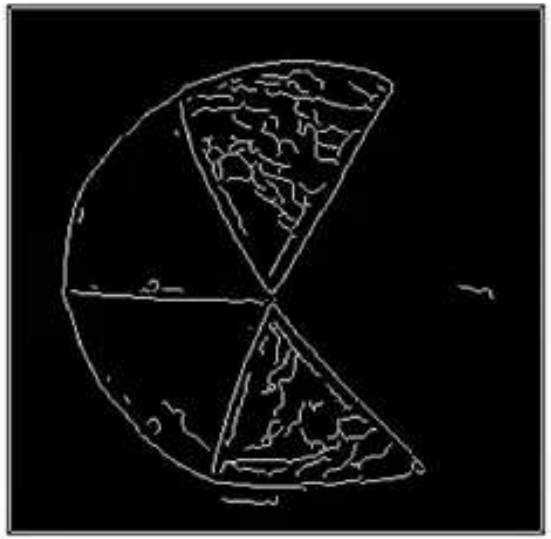
Gonzalez & Woods

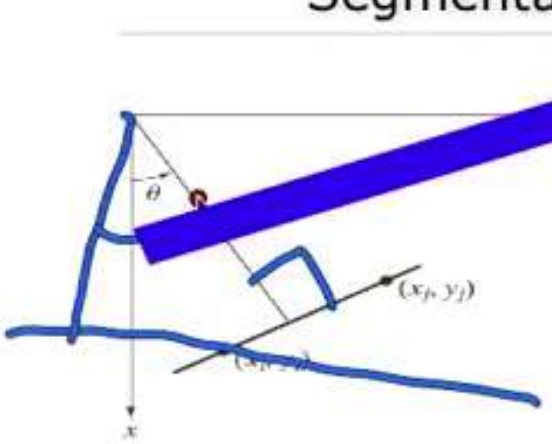
www.ImageProcessingPlace.com

Chapter 10

Segmentation

Angle measured to x axis.





$$\rho = x\cos\theta + y\sin\theta$$

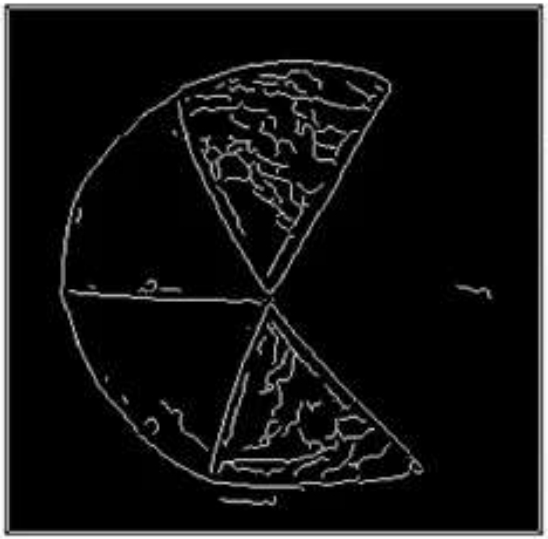
Digital Image Processing, 3rd ed.

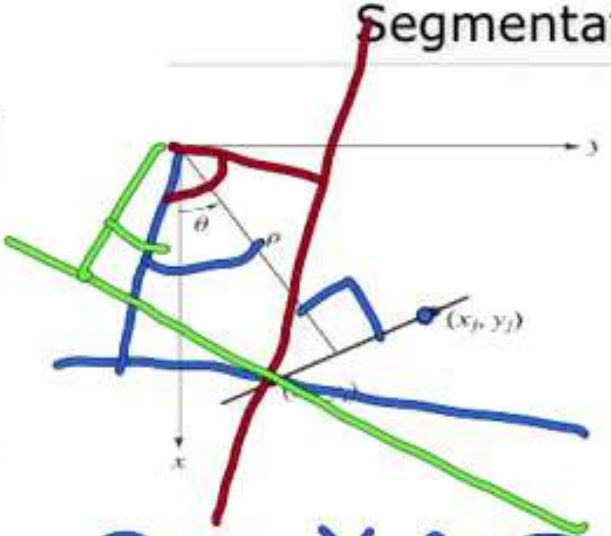
Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation





$$\rho = x\cos\theta + y\sin\theta$$

$$(\rho, \theta)$$

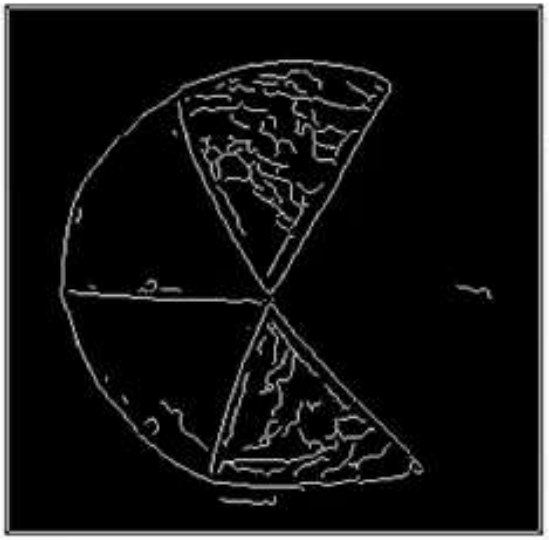
Digital Image Processing, 3rd ed.

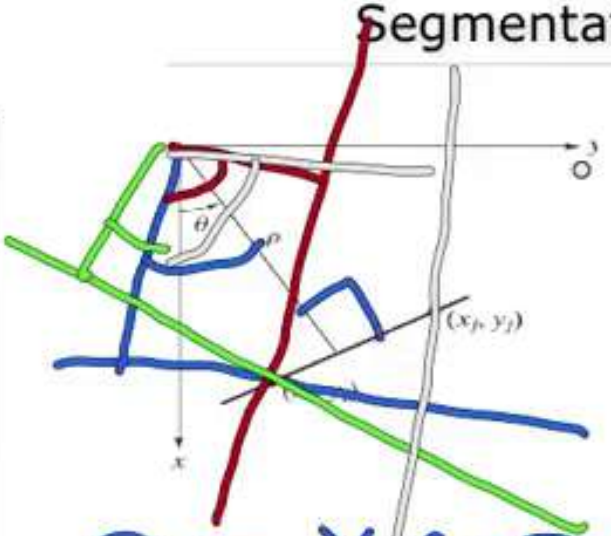
Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation





$$\rho = x\cos\theta + y\sin\theta$$

$$(\rho, \theta)$$

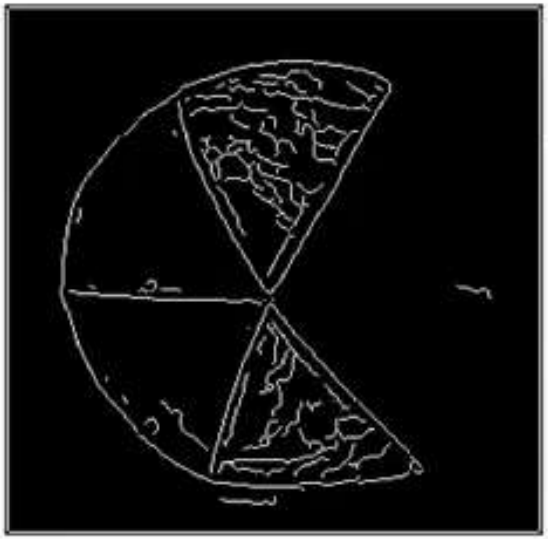
Digital Image Processing, 3rd ed.

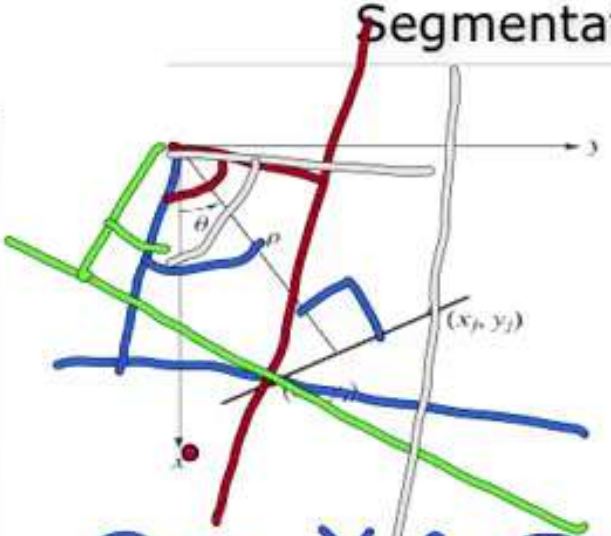
Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation





$$\rho = x\cos\theta + y\sin\theta$$

(ρ, θ) (ρ, θ)

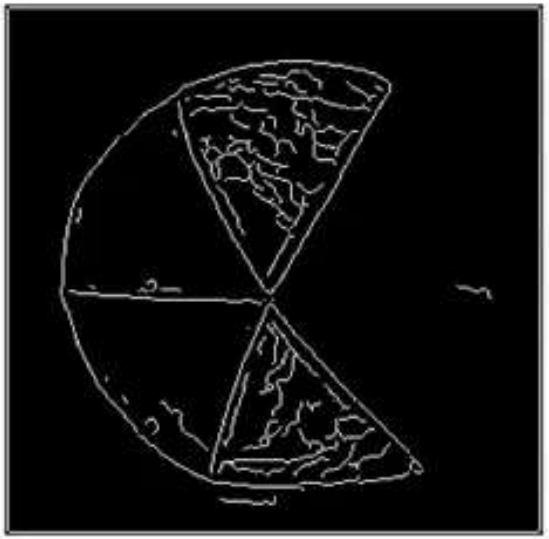
Digital Image Processing, 3rd ed.

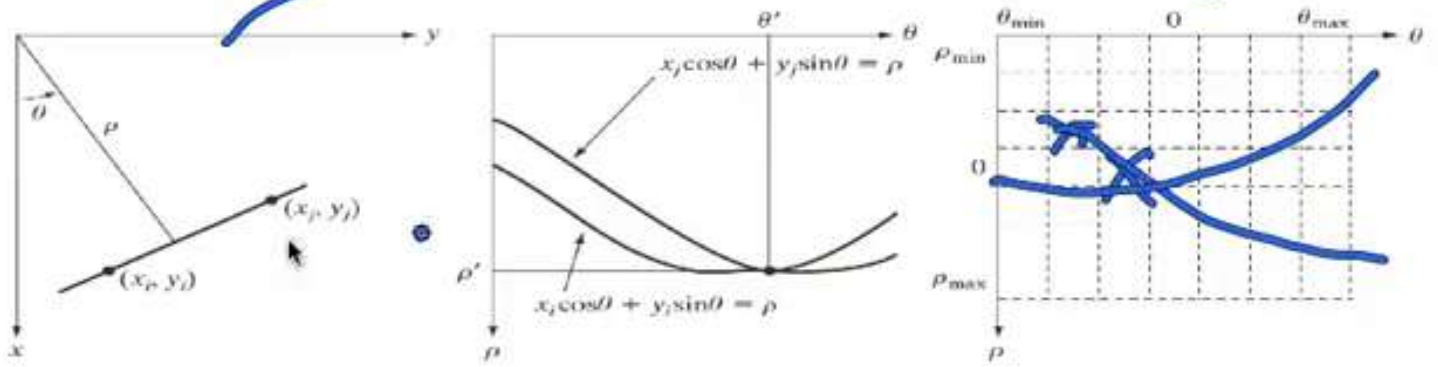
Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation





$$\rho = x\cos\theta + y\sin\theta$$

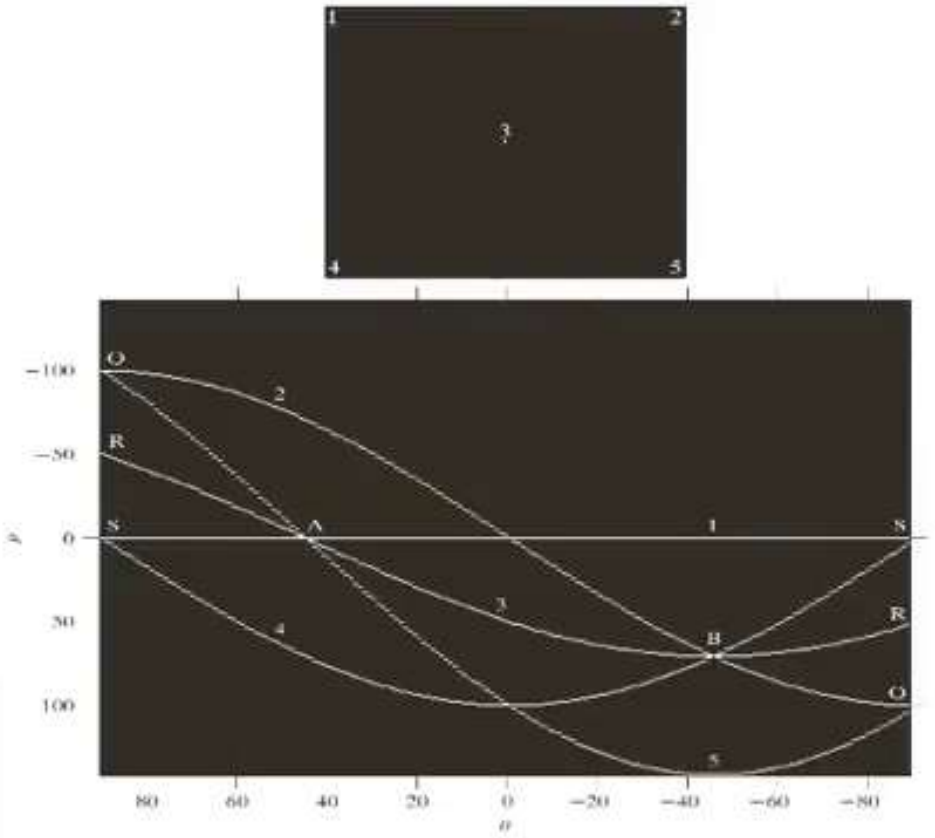
Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation



a
b

FIGURE 10.33
(a) Image of size 101 × 101 pixels, containing five points.
(b) Corresponding parameter space. (The points in (a) were enlarged to make them easier to see.)

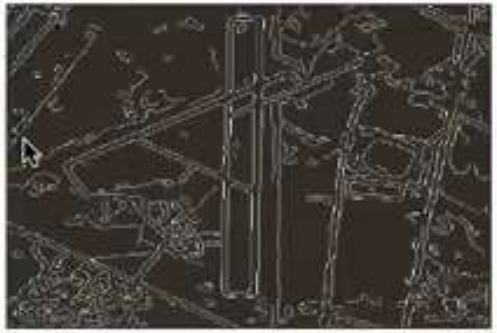
Digital Image Processing, 3rd ed.

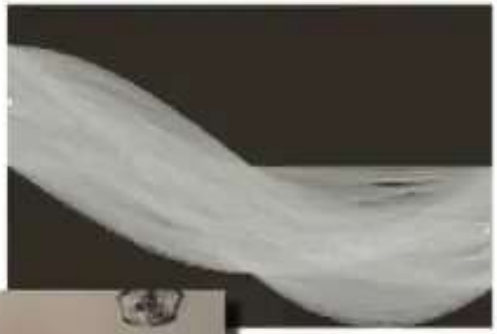
Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation





Command Window

MATLAB? Watch this Video, see Demos, or read Getting Started.

```
    len = norm(lines(k).point1 - lines(k).point2);
    if ( len > max_len)
      max_len = len;
      xy_long = xy;
    end
  end

  % highlight the longest line segment
  plot(xy_long(:,1),xy_long(:,2),'LineWidth',2,'Color','cyan');

See also hough and houghpeaks.

Reference page in Help browser
   doc houghlines

>>
   I  = imread('circuit.tif');
   rotI = imrotate(I,33,'crop');
   BW = edge(rotI,'canny');
   [H,T,R] = hough(BW);
   imshow(H,[],'XData',T,'YData',R,'InitialMagnification','fit');
   xlabel('\theta'), ylabel('\rho');
   axis on, axis normal, hold on;
   P  = houghpeaks(H,5,'threshold',ceil(0.3*max(H(:))));
   x = T(P(:,2));
   y = R(P(:,1));
   plot(x,y,'s','color','white');

   % Find lines and plot them
   lines = houghlines(BW,T,R,P,'FillGap',5,'MinLength',7);
   figure, imshow(rotI), hold on
   max_len = 0;
   for k = 1:length(lines)
     xy = [lines(k).point1; lines(k).point2];
     plot(xy(:,1),xy(:,2),'LineWidth',2,'Color','green');

     % plot beginnings and ends of lines
     plot(xy(1,1),xy(1,2),'x','LineWidth',2,'Color','yellow');
     plot(xy(2,1),xy(2,2),'x','LineWidth',2,'Color','red');

     % determine the endpoints of the longest line segment
     len = norm(lines(k).point1 - lines(k).point2);
     if ( len > max_len)
       max_len = len;
       xy_long = xy;
     end
   end
fx >>
```

Workspace

Name

- BW
- H
- I
- P
- R
- T
- ball
- e
- im
- k
- len
- lines
- max_len
- radii
- rotI
- x
- xy

Select a file to view details

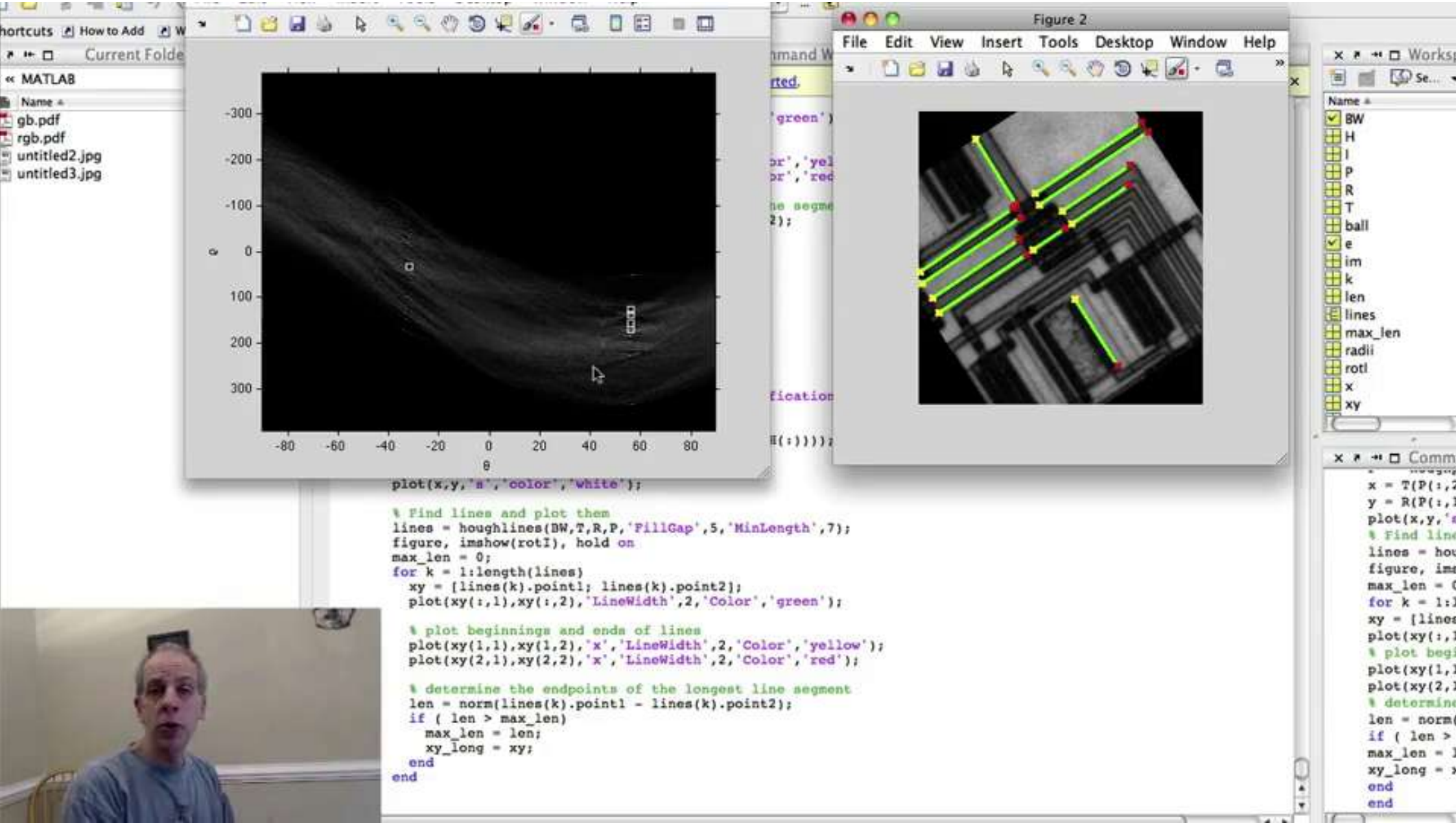
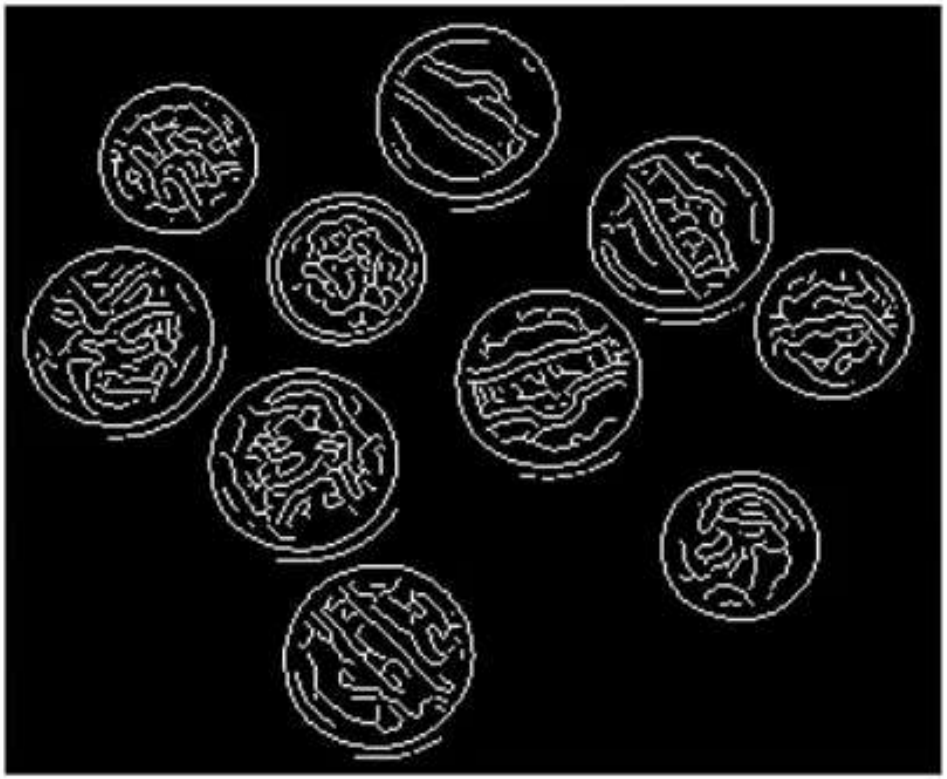
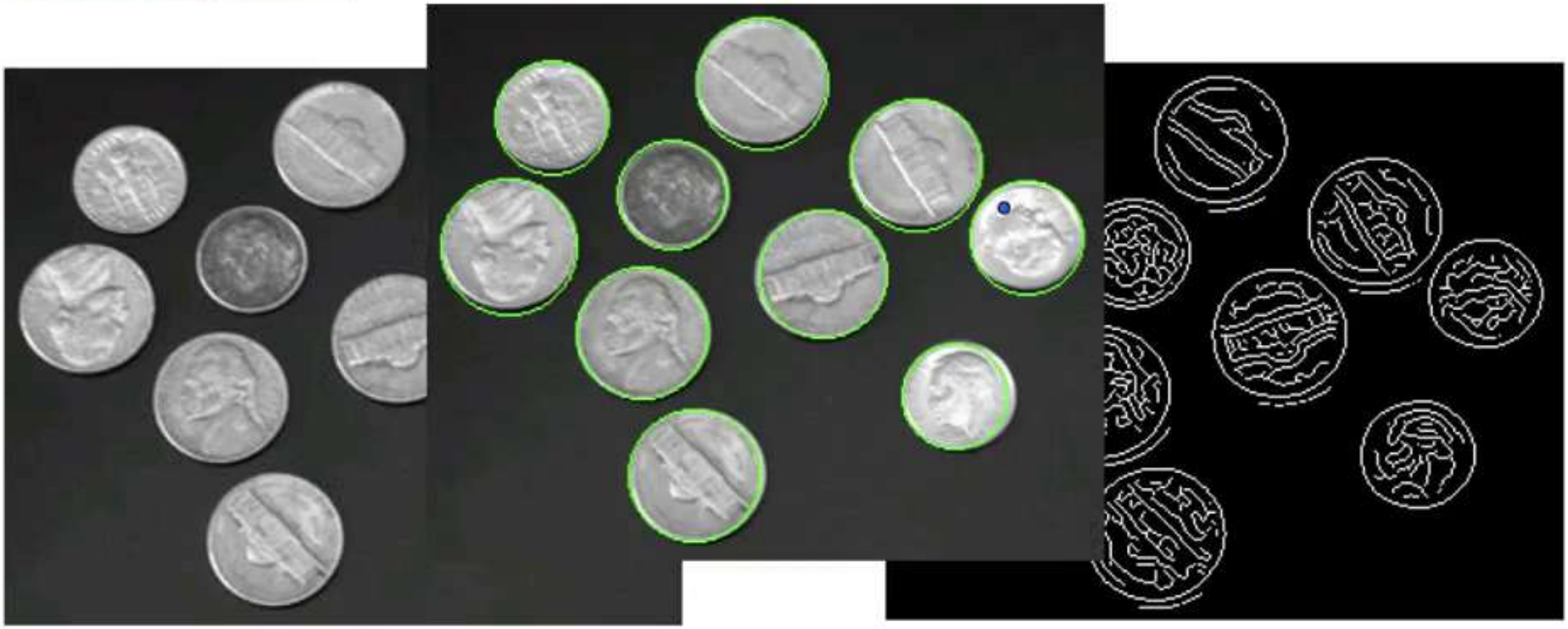


Figure 2
File Edit View Insert Tools Desktop Window Help
-300
-200
-100
0
100
200
300
-80 -60 -40 -20 0 20 40 60 80
θ
ρ
plot(x,y,'s','color','white');
% Find lines and plot them
lines = houghlines(BW,T,R,P,'FillGap',5,'MinLength',7);
figure, imshow(rotI), hold on
max_len = 0;
for k = 1:length(lines)
xy = [lines(k).point1; lines(k).point2];
plot(xy(:,1),xy(:,2),'LineWidth',2,'Color','green');
% plot beginnings and ends of lines
plot(xy(1,1),xy(1,2),'x','LineWidth',2,'Color','yellow');
plot(xy(2,1),xy(2,2),'x','LineWidth',2,'Color','red');
% determine the endpoints of the longest line segment
len = norm(lines(k).point1 - lines(k).point2);
if (len > max_len)
max_len = len;
xy_long = xy;
end
end
MATLAB
Name
gb.pdf
rgb.pdf
untitled2.jpg
untitled3.jpg
BW
H
I
P
R
T
ball
e
im
k
len
lines
max_len
radii
rotI
x
xy

What About Circles?



What About Circles?



Images courtesy of D. Young and Mathworks

www.ipol.im/pub/art/2012/gjmr-lsd/

Image Processing On Line

LSD: a Line Segment Detector

Rafael Grompone von Gioi, Jérémie Jakubowicz, Jean-Michel Morel, Gregory Randall

article | demo | archive

published • 2012-03-24
reference • Grompone von Gioi, Rafael, Jérémie Jakubowicz, Jean-Michel Morel, and Gregory Randall. "LSD: a Line Segment Detector." *Image Processing On Line* 2012 (2012). http://dx.doi.org/10.5201/ipol.2012.gjmr-lsd

- full text manuscript: PDF high-res. [?]
- source code: ZIP

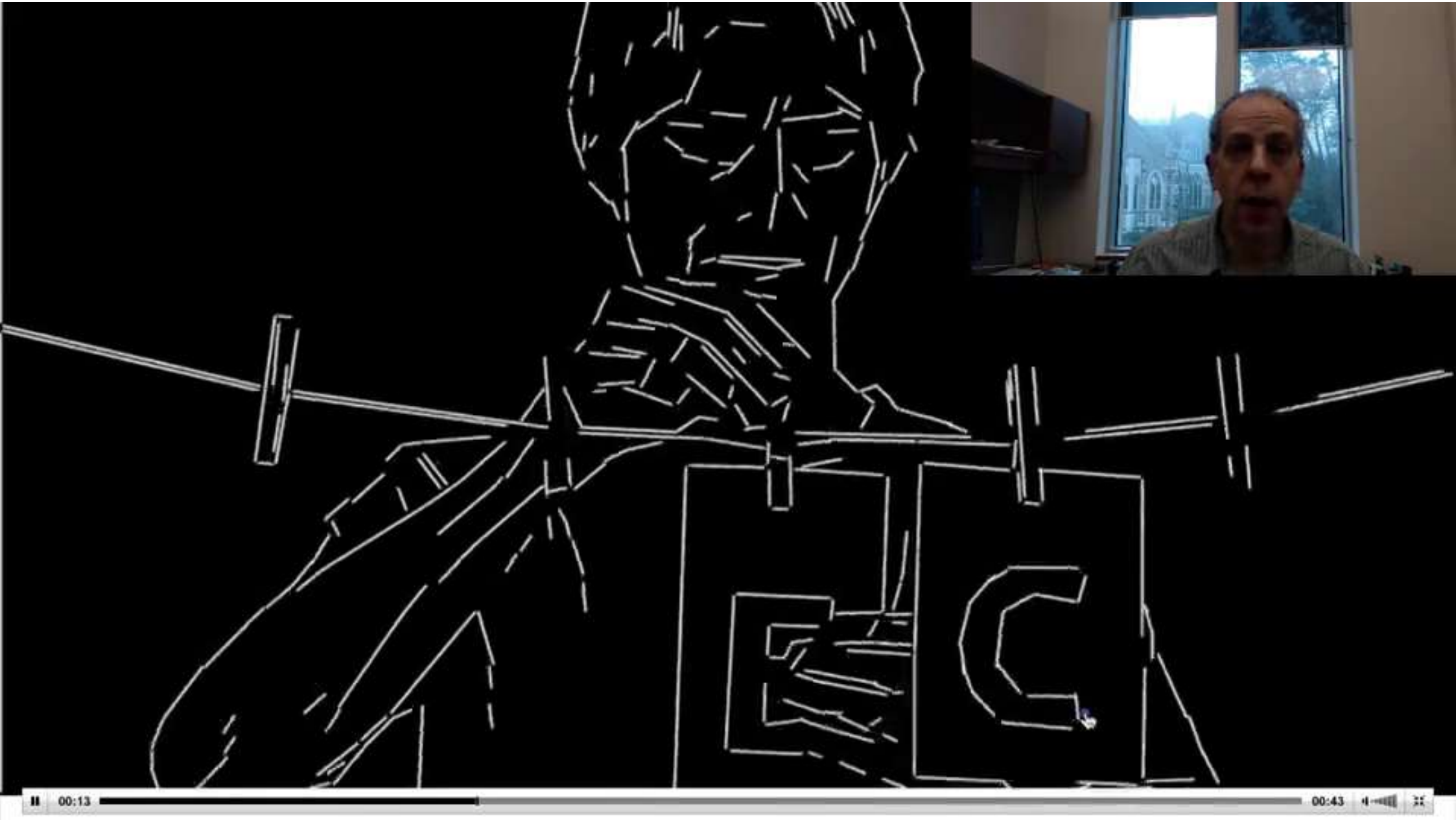
Communicated by Lionel Moisan
Demo edited by Rafael Grompone

Abstract

LSD is a linear-time Line Segment Detector giving subpixel accurate results. It is designed to work on any digital image without parameter tuning. It controls its own number of false detections: On average, one false alarms is allowed per image. The method is based on Burns, Hanson, and Riseman's method, and uses an a-contrario validation approach according to Desolneux, Moisan, and Morel's theory. The version described here includes some further improvement over the one described in the original article.

Supplementary Material

- sample video: MP4 [?]


00:13
00:43

demo.ipol.im/demo/gjmr_line_segment_detector/input_select?chairs.x=50&chairs.y=55

Image Processing On Line

HOME · ABOUT · ARTICLES · PREPRINTS · NEWS · SEARCH

LSD: a Line Segment Detector

article | demo | archive

Please cite the reference article if you publish results obtained with this online demo.

The image was converted to gray level values.

Run the algorithm: run

Or you can run it after selecting a subimage by clicking two opposite corners of the subimage.

demo.ipol.im/demo/gjmr_line_segment_detector/result?key=EB02C5128E963A9338DAD05925CBB4CE

article | demo | archive

Please cite the reference article if you publish results obtained with this online demo.

Run again? new image | different subimage

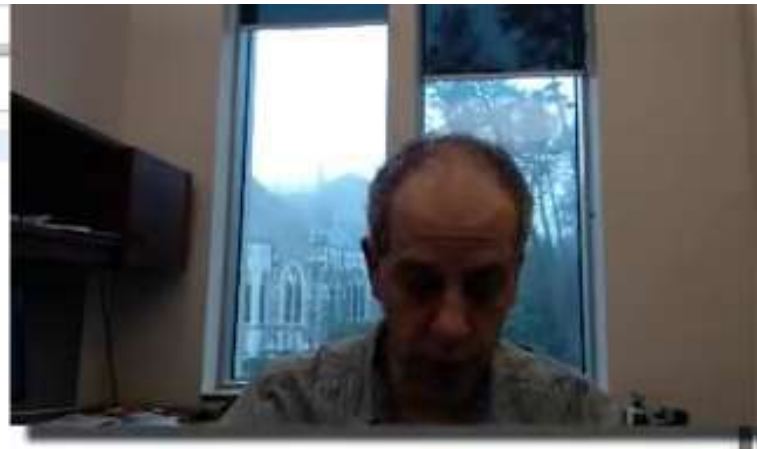
Result

698 Line Segments were detected. The algorithm ran in 0.22s.

You can download the result in EPS format, in SVG format, or an ASCII file (see description below).

output

input



demo.ipol.im/demo/gjmr_line_segment_detector/result?key=2395A1C81D1F9C8CDF617E61AC9CED02

Result

847 Line Segments were detected. The algorithm ran in 0.28s.

You can download the result in EPS format, in SVG format, or an ASCII file (see description below).

output

input

demo.ipol.im/demo/gjmr_line_segment_detector/result?key=2395A1C81D1F9C8CDF617E61AC9CED02

Result

847 Line Segments were detected. The algorithm ran in 0.28s.

You can download the result in EPS format, in SVG format, or an ASCII file (see description below).

output

input

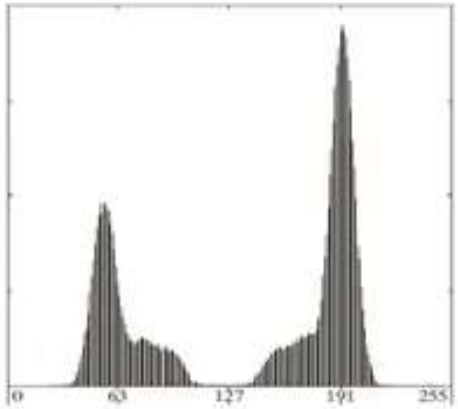
Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation



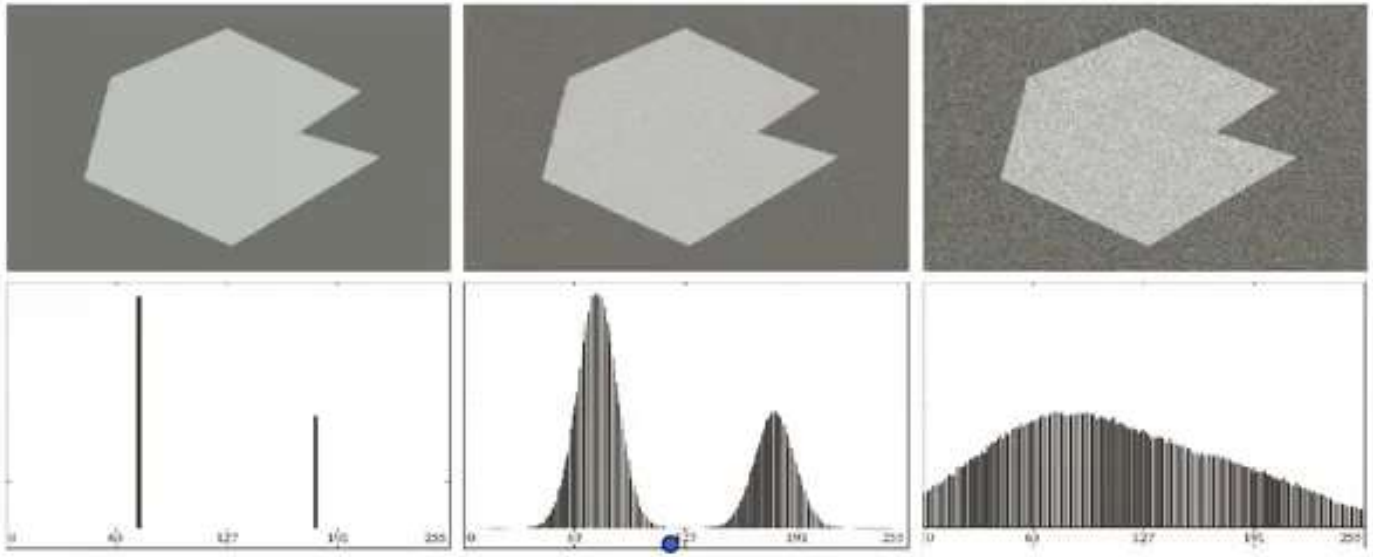
Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation



a b c
d e f

FIGURE 10.36 (a) Noiseless 8-bit image. (b) Image with additive Gaussian noise of mean 0 and standard deviation of 10 intensity levels. (c) Image with additive Gaussian noise of mean 0 and standard deviation of 50 intensity levels. (d)–(f) Corresponding histograms.

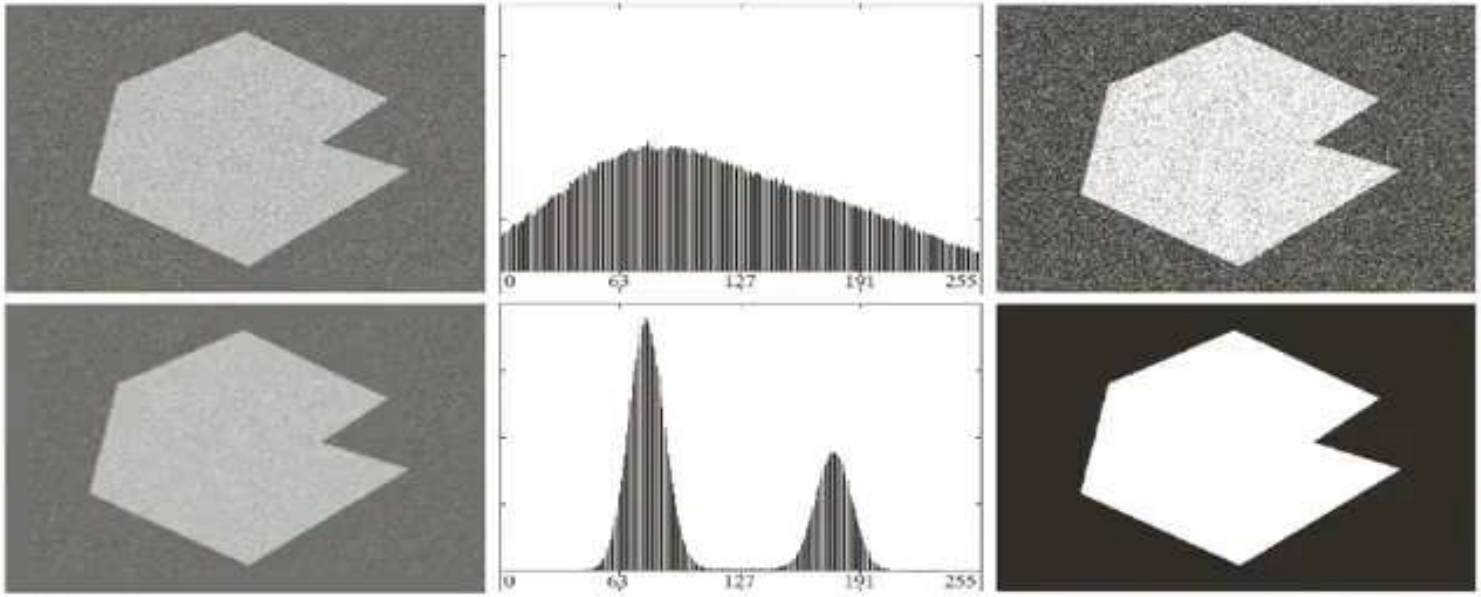
Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 10

Segmentation



a b c
d e f

FIGURE 10.40 (a) Noisy image from Fig. 10.36 and (b) its histogram. (c) Result obtained using Otsu's method. (d) Noisy image smoothed using a 5×5 averaging mask and (e) its histogram. (f) Result of thresholding using Otsu's method.

Minimize the *weighted within-class variance*:

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$

$$q_1(t) = \sum_{i=1}^{t} P(i) \qquad q_2(t) = \sum_{i=t+1}^{I} P(i)$$

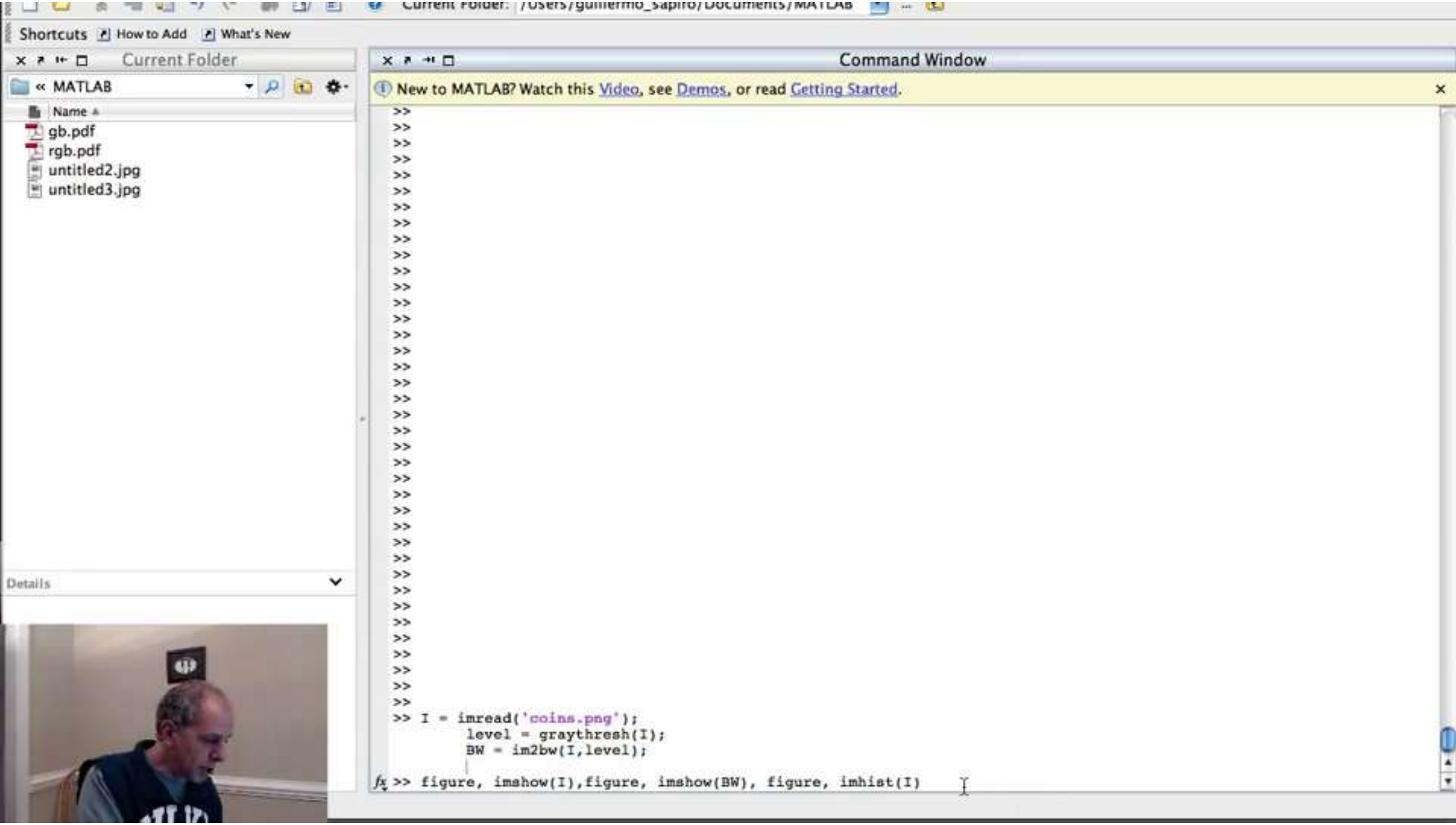
$$\mu_1(t) = \sum_{i=1}^{t} \frac{iP(i)}{q_1(t)} \qquad \mu_2(t) = \sum_{i=t+1}^{I} \frac{iP(i)}{q_2(t)}$$

$$\sigma_1^2(t) = \sum_{i=1}^{t} [i - \mu_1(t)]^2 \frac{P(i)}{q_1(t)} \qquad \sigma_2^2(t) = \sum_{i=t+1}^{I} [i - \mu_2(t)]^2 \frac{P(i)}{q_2(t)}$$

Minimize the *weighted within-class variance*:

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$

$$\sigma^2 = \underbrace{\sigma_w^2(t)}_{\text{Within-class}} + \underbrace{q_1(t)[1 - q_1(t)][\mu_1(t) - \mu_2(t)]^2}_{\text{Between-class}}$$


Current Folder: /Users/guillermo_sapiro/Documents/MATLAB
Shortcuts
How to Add
What's New
Current Folder
MATLAB
Name
gb.pdf
rgb.pdf
untitled2.jpg
untitled3.jpg
Details
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
>> I = imread('coins.png');
level = graythresh(I);
BW = im2bw(I,level);
>> figure, imshow(I),figure, imshow(BW), figure, imhist(I)

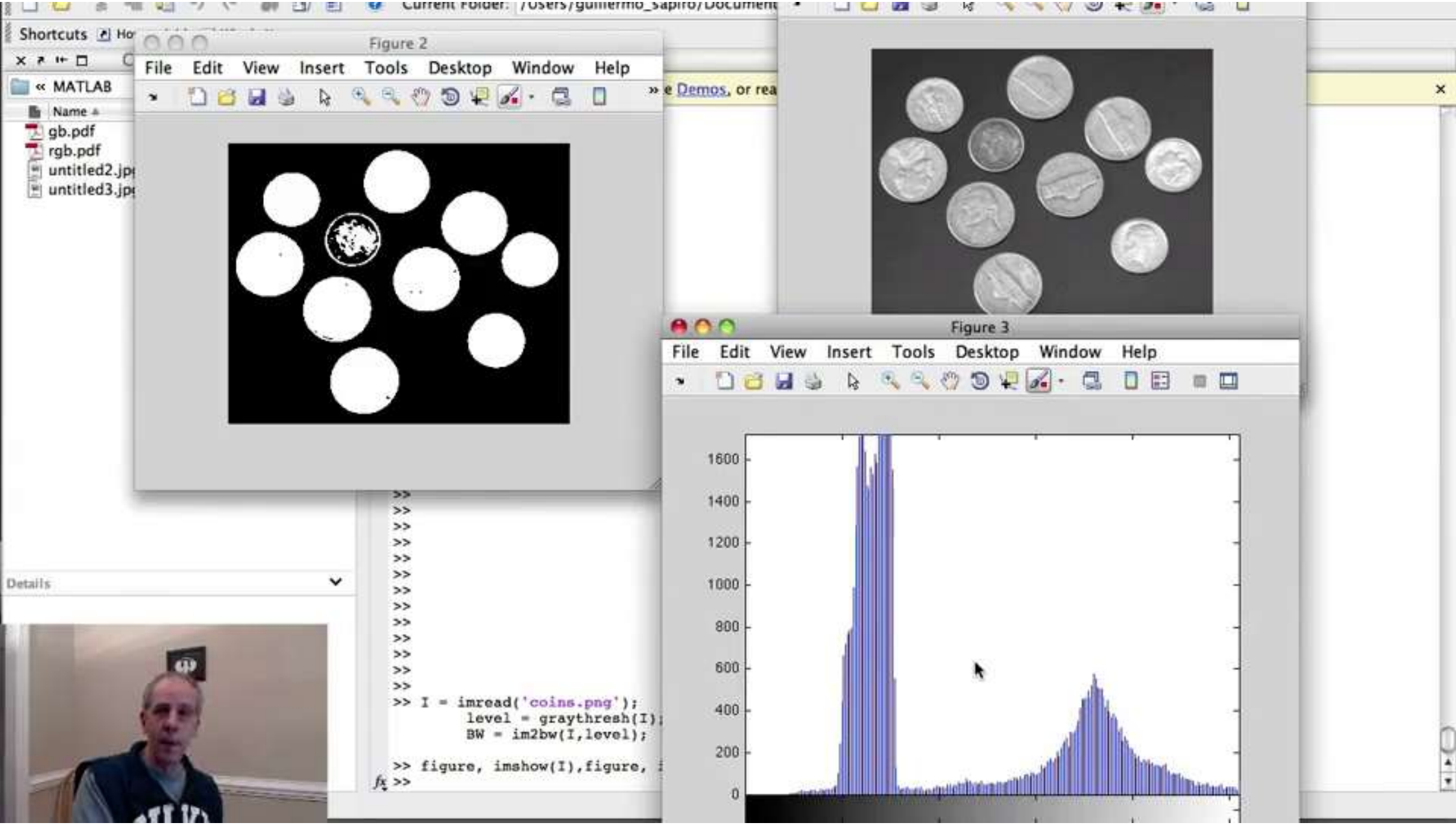
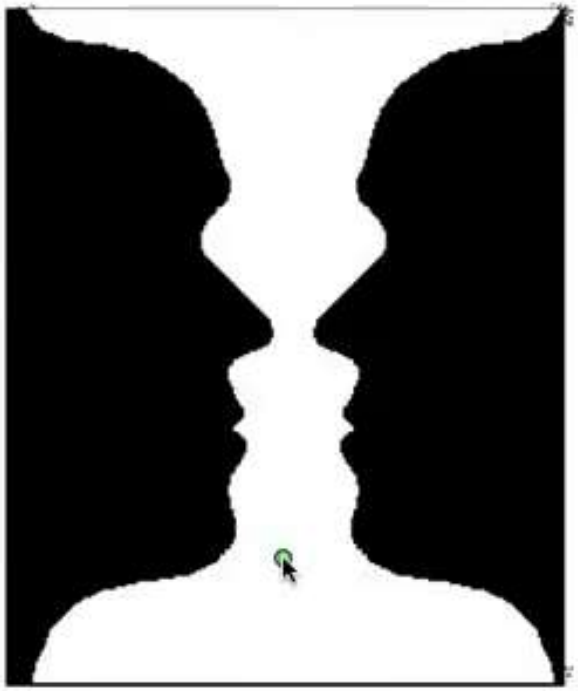


Figure 2
File Edit View Insert Tools Desktop Window Help
Figure 3
File Edit View Insert Tools Desktop Window Help
1600
1400
1200
1000
800
600
400
200
0
>> I = imread('coins.png');
level = graythresh(I);
BW = im2bw(I,level);
>> figure, imshow(I),figure,
>>
« MATLAB
Name
gb.pdf
rgb.pdf
Details
Shortcuts

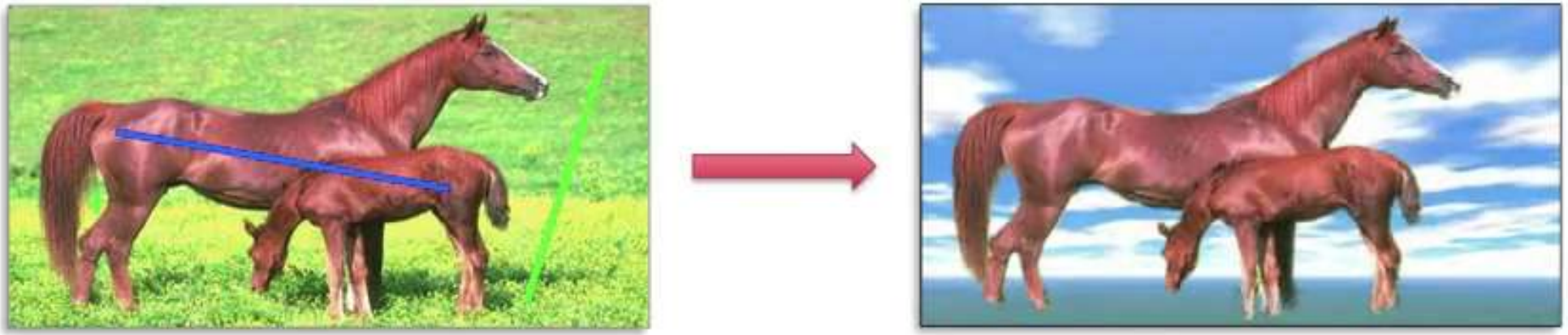
Automatic Segmentation is Tough!

By Doolittle

Automatic Segmentation is Tough!



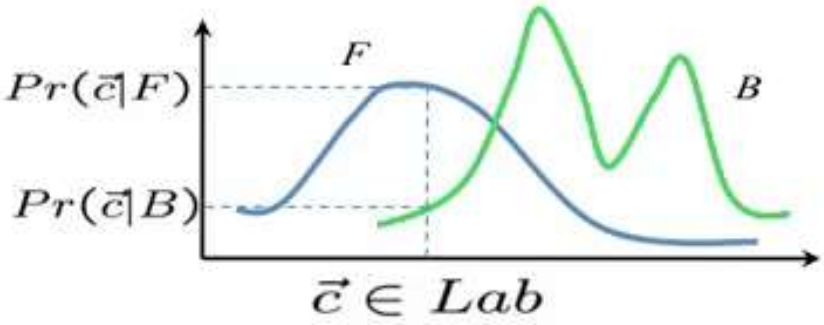
Interactive image segmentation



Step1 – Feature Distribution Estimation

- Estimate the color distribution on scribbles

- Each pixel is assigned a probability to belong to F or B:

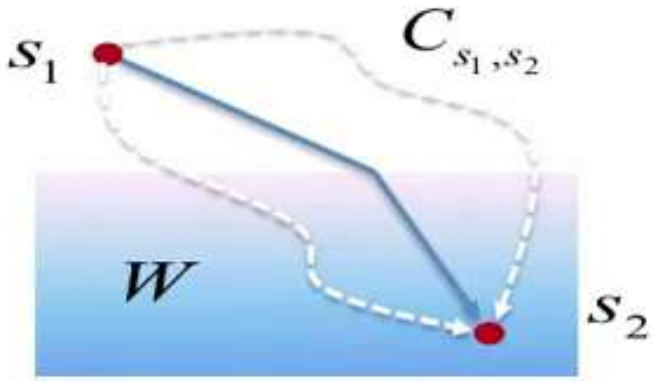


$$P_F(x) = \frac{Pr(\vec{c_x}|F)}{Pr(\vec{c_x}|F) + Pr(\vec{c_x}|B)}$$

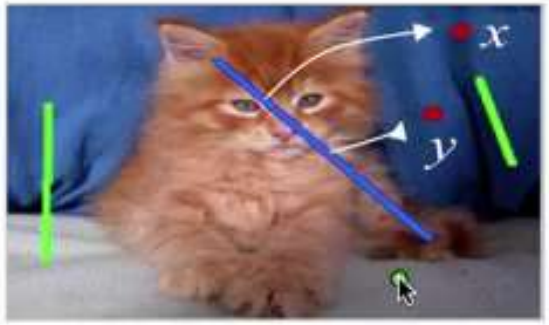
Step2 – Weighted Distance Transform

Weighted Geodesic Distance

$$d(s_1, s_2) := \min_{C_{s_1,s_2}} \int_{C_{s_1,s_2}} W ds$$



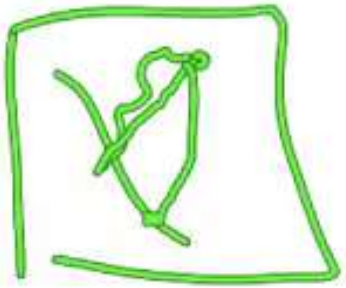
- Computed in linear time!



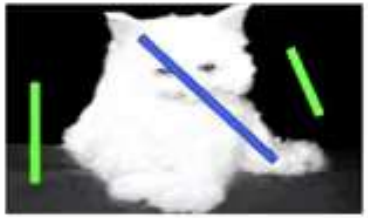
Weighted Distance Transform (cont'd)

$$W := |\nabla P_F(x) \cdot \vec{C}'_{s_1,s_2}(x)|$$

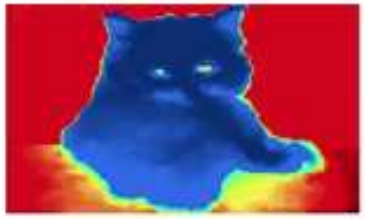
$$D_l(x) := \min_{s \in \Omega_l} d(s,x), \quad l \in \{F, B\}$$



- Pixels are classified by comparing $D_F(x)$ and $D_B(x)$



$P_F(x)$



$D_F(x)$

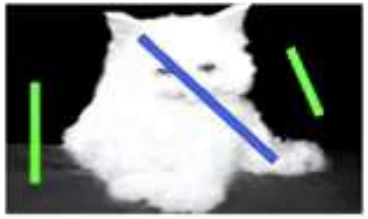
$D_B(x)$

Weighted Distance Transform

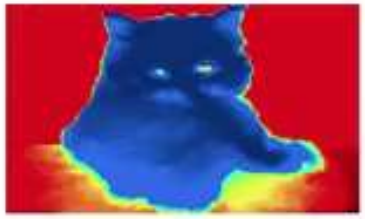
$$W := |\nabla P_F(x) \cdot \vec{C}'_{s_1,s_2}(x)|$$

$$D_l(x) := \min_{s \in \Omega_l} d(s,x), \quad l \in \{F, B\}$$

- Pixels are classified by comparing $D_F(x)$ and $D_B(x)$

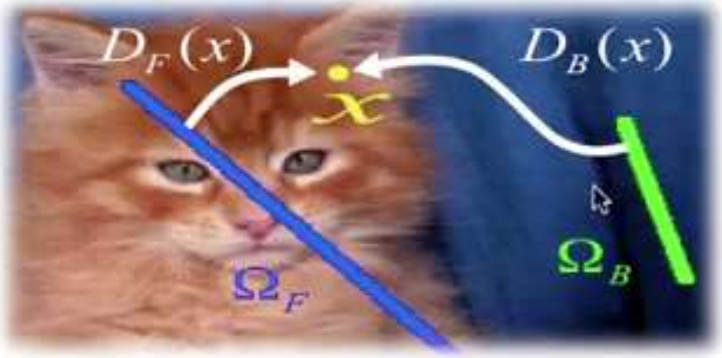


$P_F(x)$



$D_F(x)$

$D_B(x)$



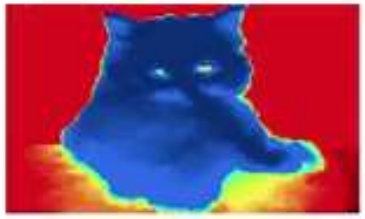
Weighted Distance Transform

$$W := |\nabla P_F(x) \cdot \vec{C}'_{s_1,s_2}(x)|$$

$$D_l(x) := \min_{s \in \Omega_l} d(s,x), \quad l \in \{F, B\}$$

- Pixels are classified by comparing $D_F(x)$ and $D_B(x)$

$P_F(x)$



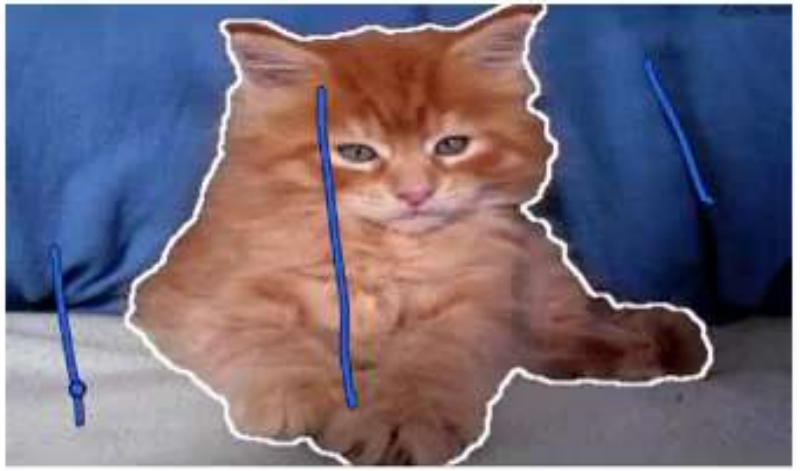
$D_F(x)$

$D_B(x)$

binary segmentation

Step3 – Refine

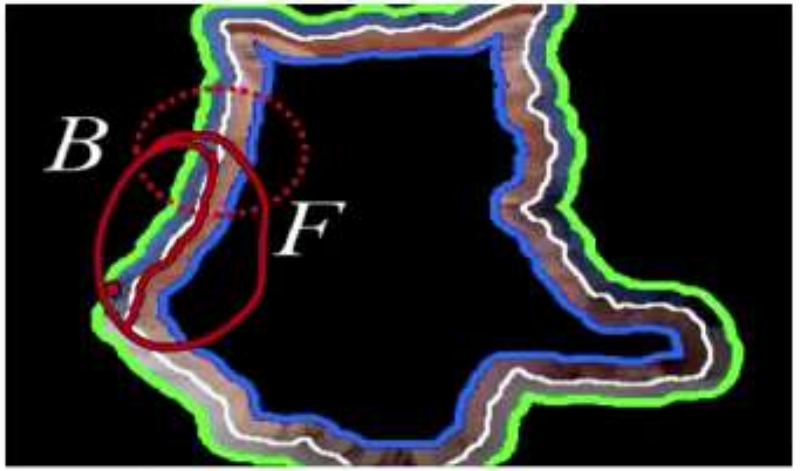
- Automatically create a narrow band and new scribbles.
  - Band boundaries serve as “new scribbles”



Step3 – Refine

- Automatically create a narrow band and new scribbles.
  - Band boundaries serve as “new scribbles”

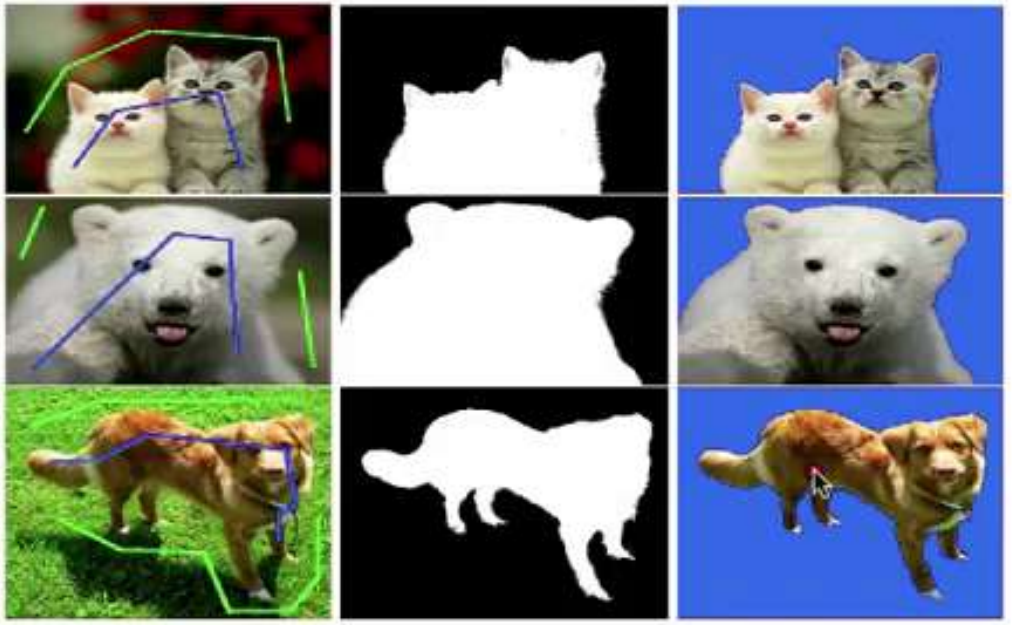
p_F



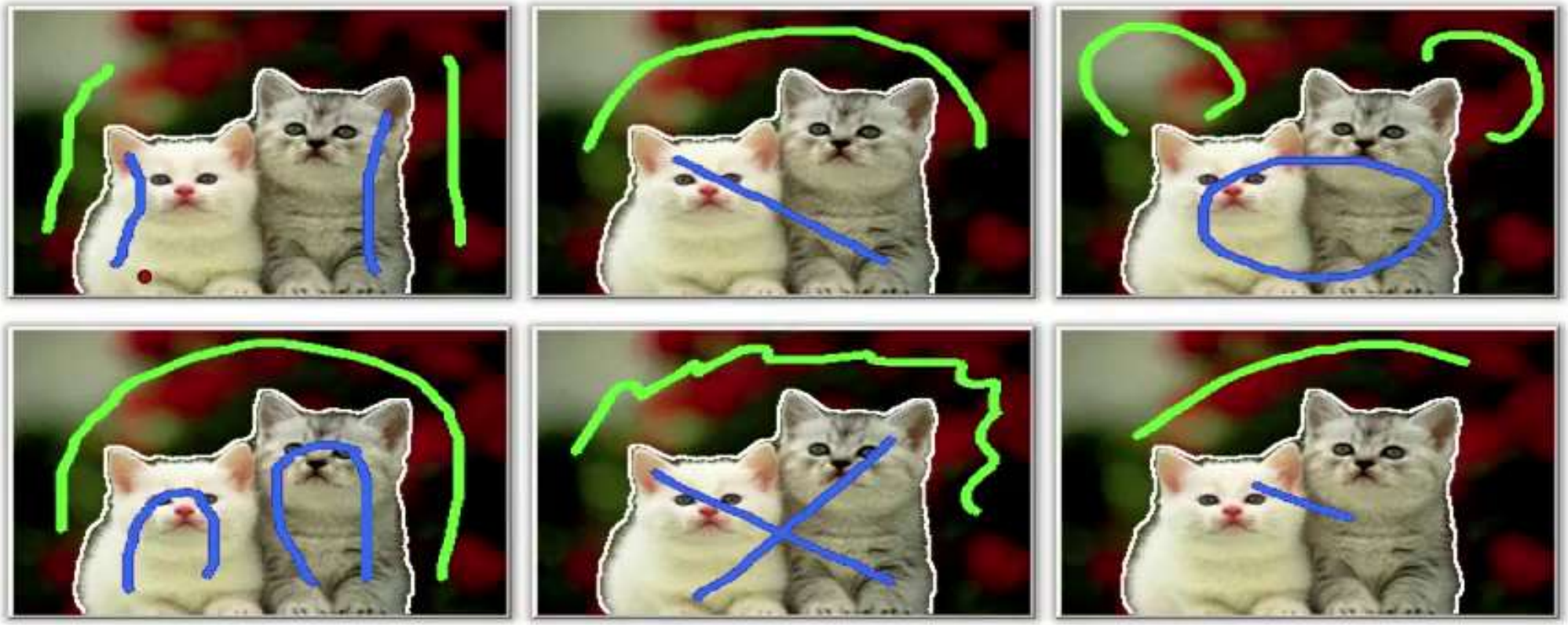
Step3 – Refine

- Automatically create a narrow band and new scribbles.
  - Band boundaries serve as “new scribbles”

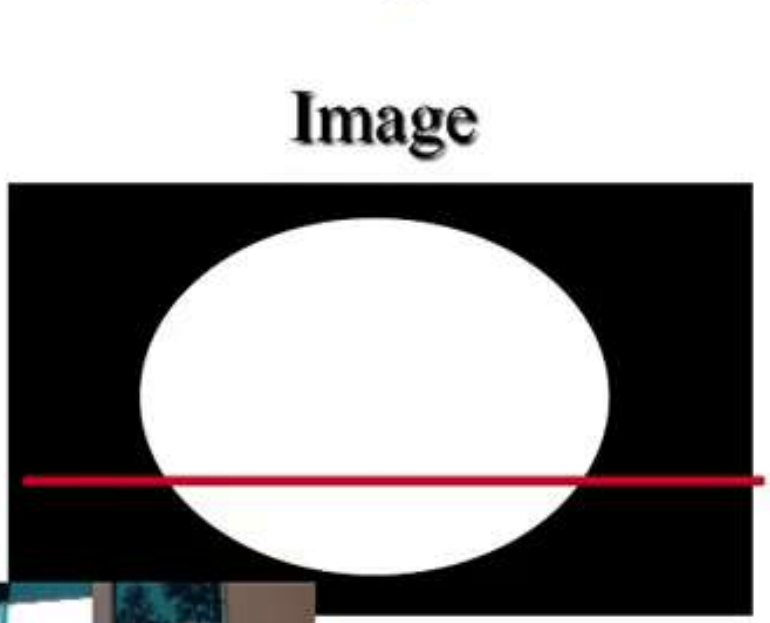
Examples

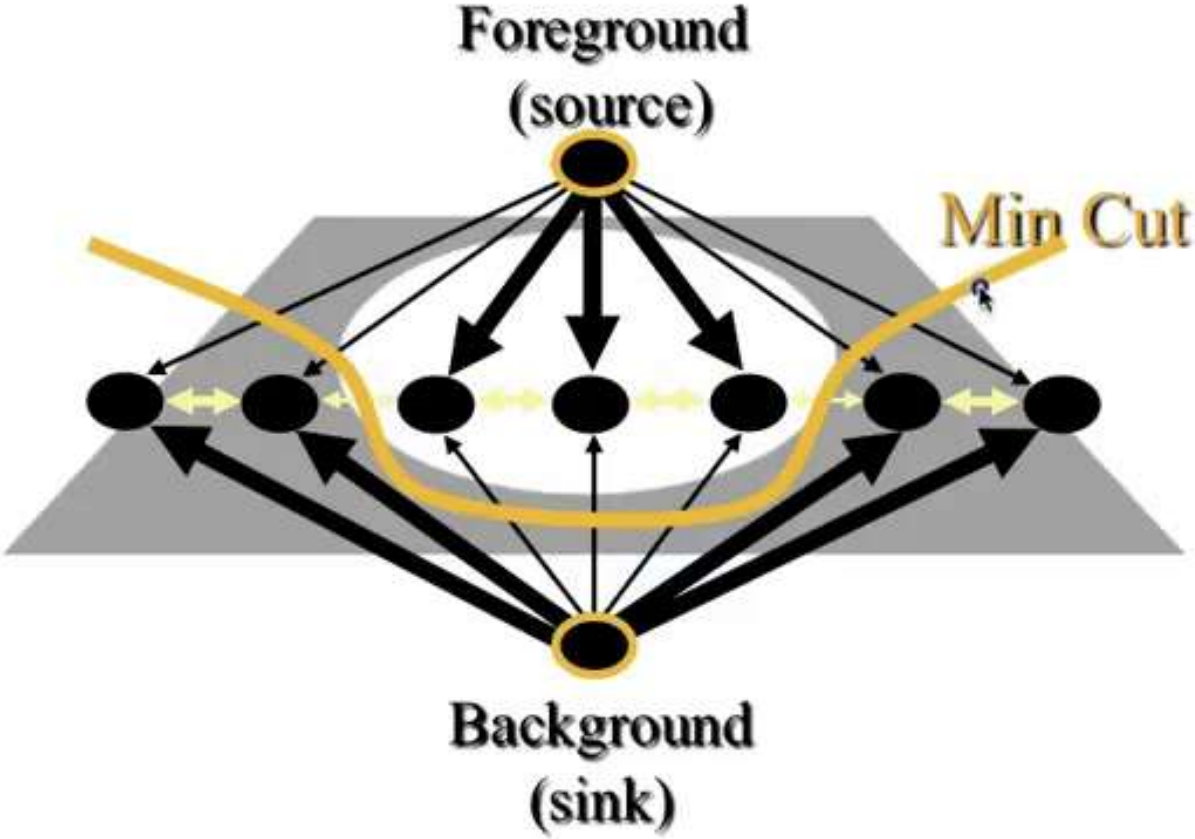


Scribble Robustness



Graph Cuts - Boykov and Jolly (2001)





Cut: separating source and sink; Penalty: collection of edges

Min Cut: Global minimal enegry in polynomial time

Photomontage

Courtesy of Carsten Rother

Photomontage

Courtesy of Carsten Rother

Photomontage

Courtesy of Carsten Rother

Photomontage

Courtesy of Carsten Rother

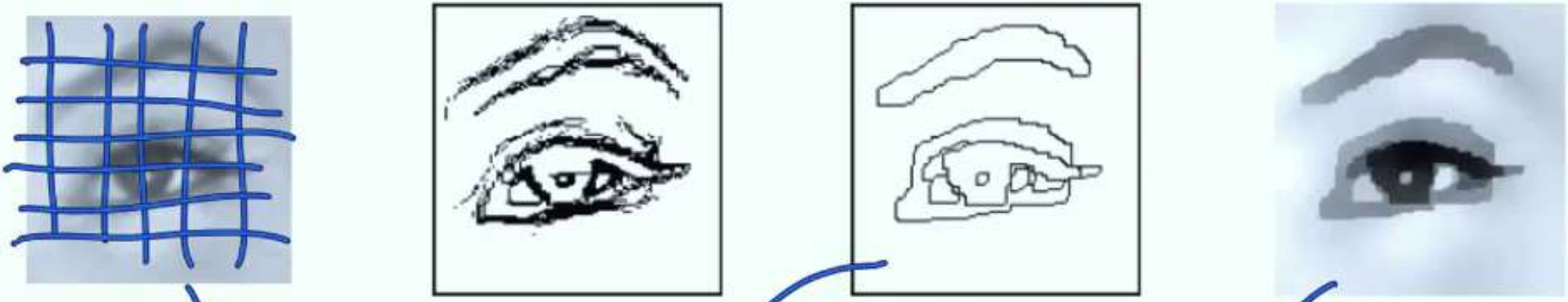


Image courtesy of Alan Yuille

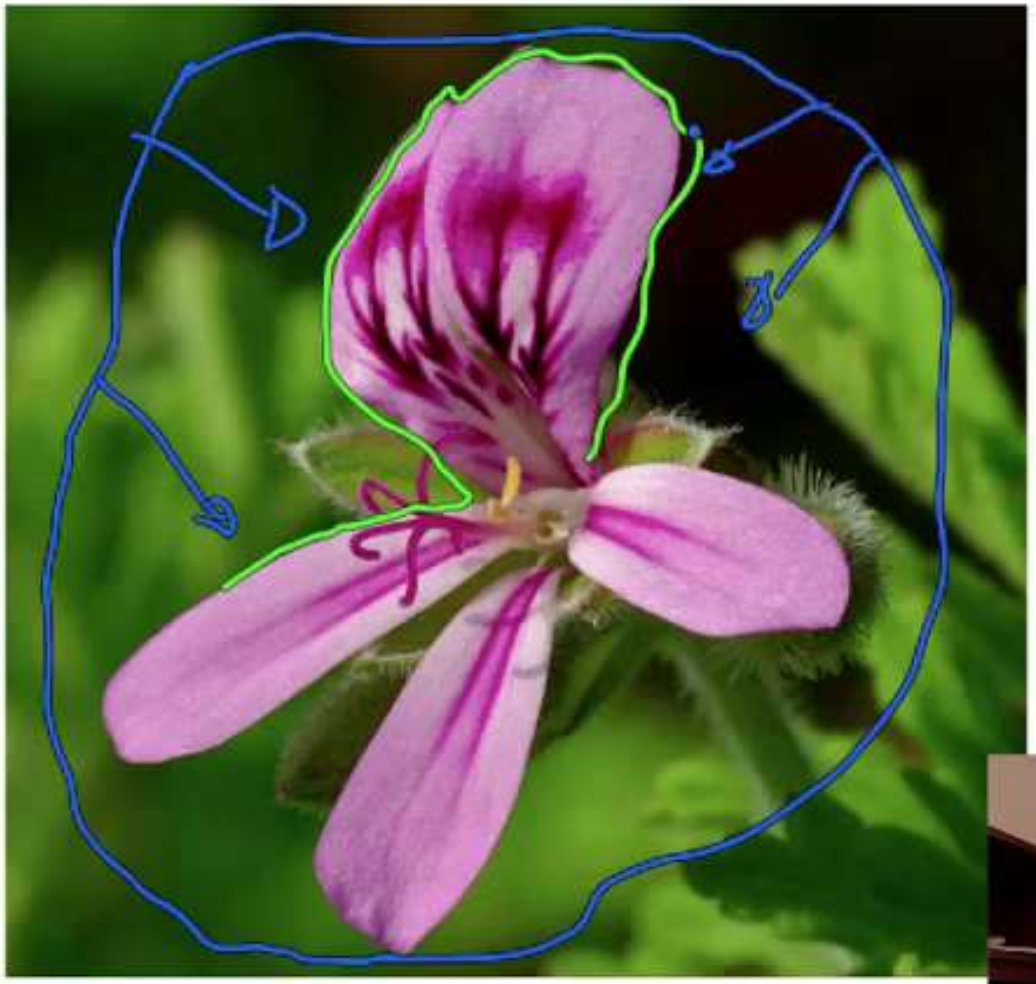
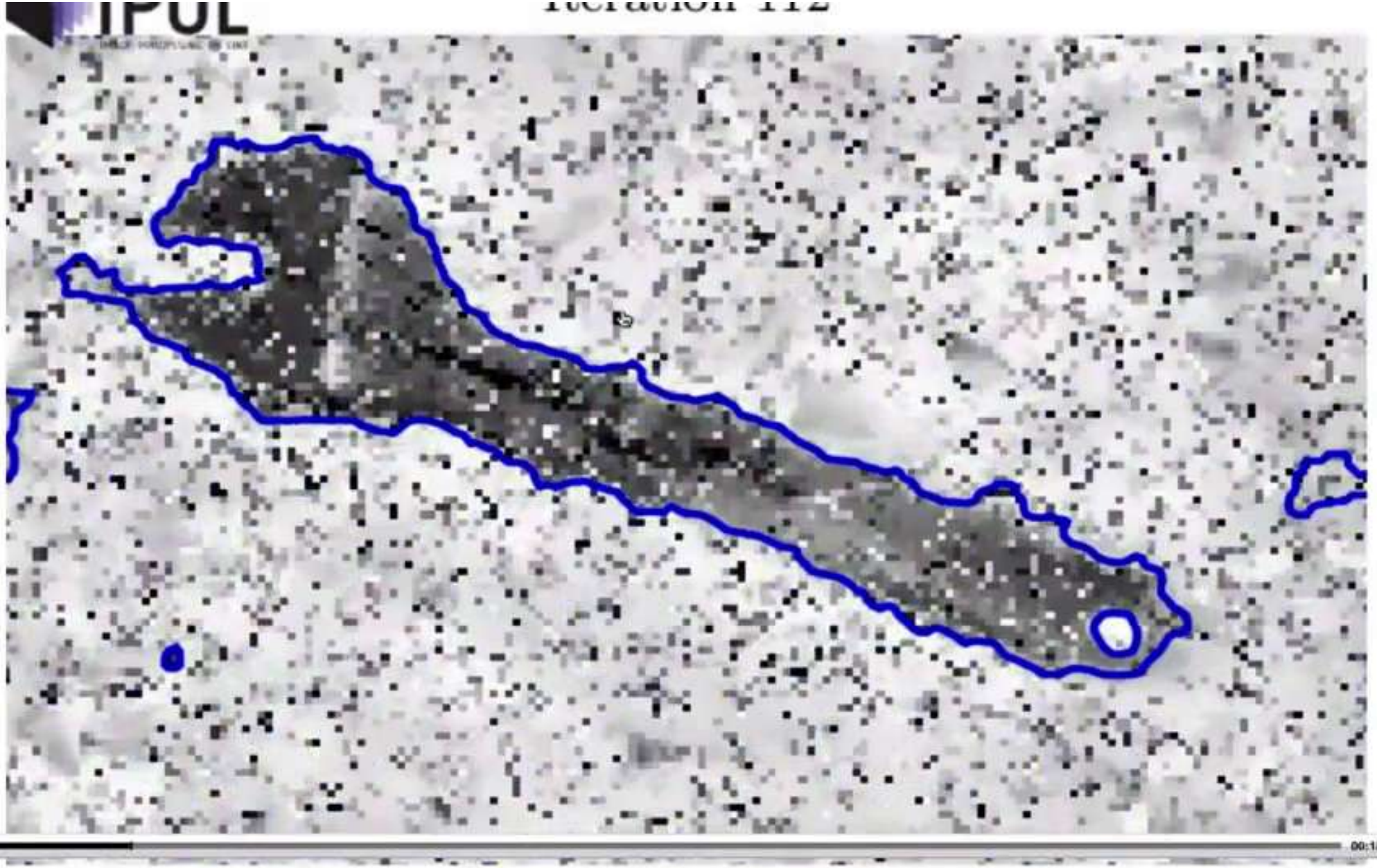
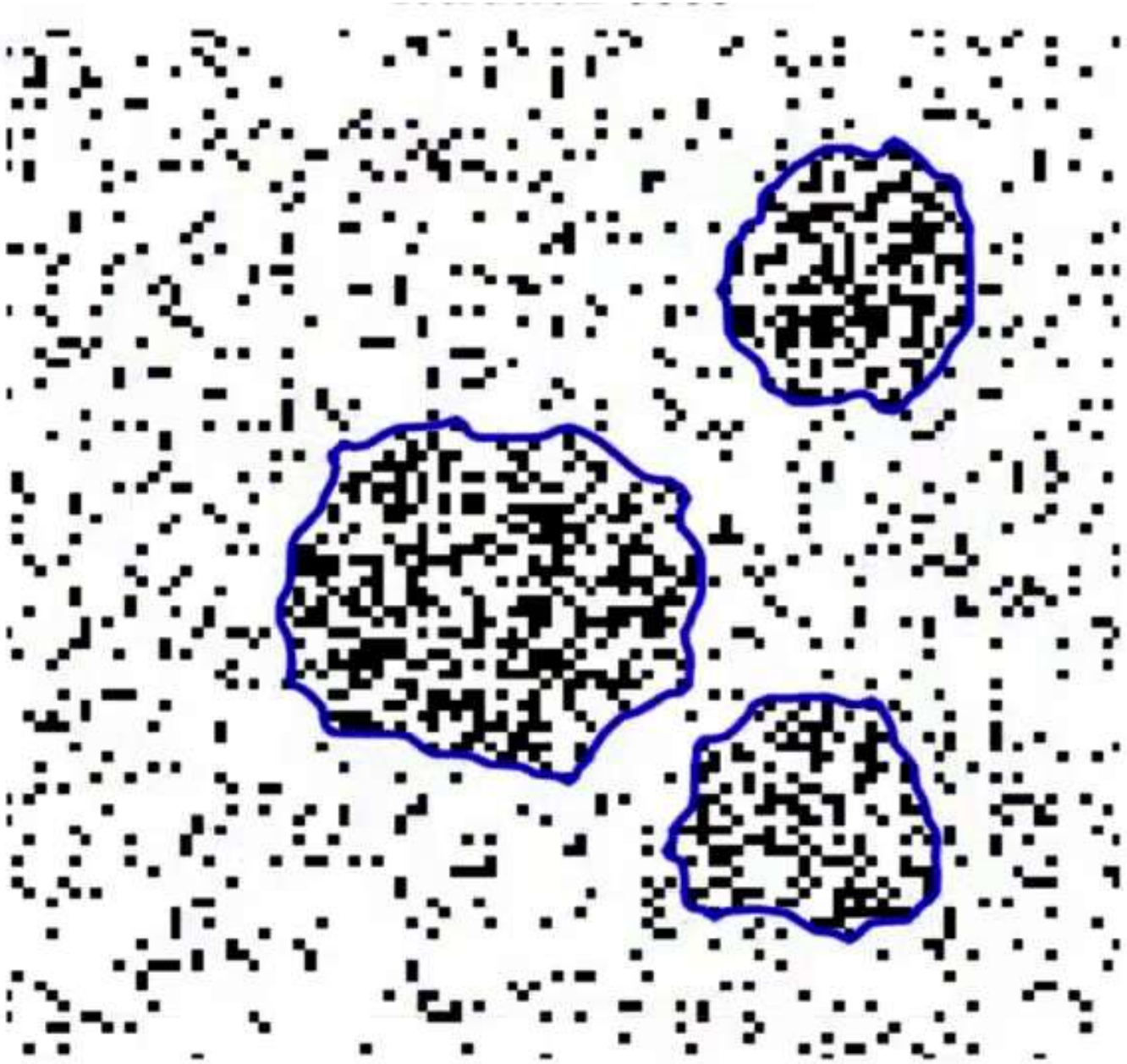
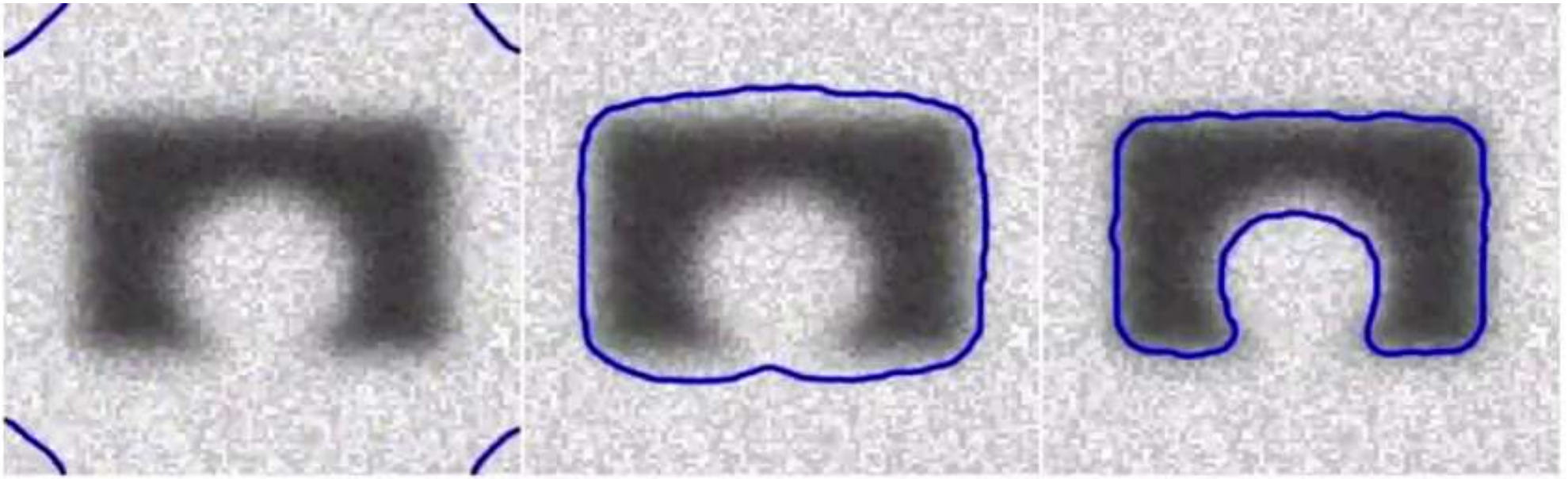


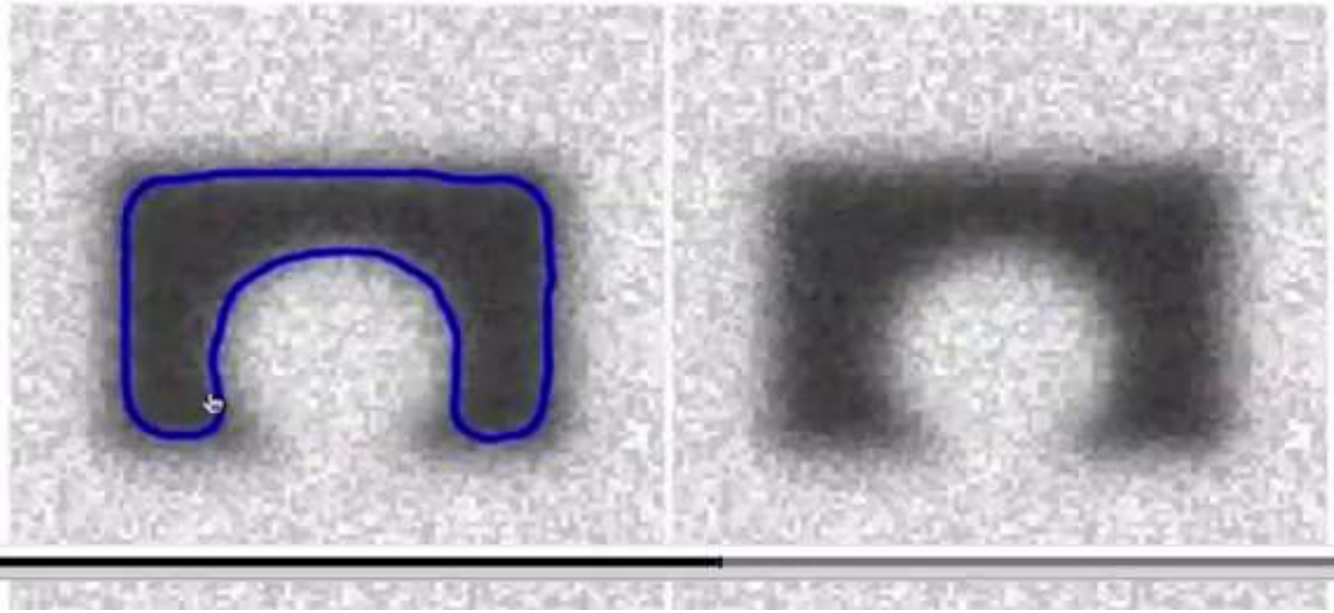
Image courtesy of ipol.im


IPUL
Iteration 112
00:02
00:18





$\nu = 0.1$ $\nu = 0.3$



00:09 00:18


demo.ipol.im/demo/g_chan_vese_segmentation/result?key=0D20A19ED590C1595E1084D733507C3A
Apple
Yahoo!
Google Maps
Wikipedia
News
Popular
YouTube
Imported From Safari
Evolution
Segmentation
Input
demo.ipol.im/demo/g_chan_vese_segmentation/result?key=0D20A19ED590C1595E1084D733507C3A#

Behind Roto Brush:

Image and Video Processing: From Mars to Hollywood with a Stop at the Hospital

Guillermo Sapiro

Duke
UNIVERSITY

Adobe's Video Segmentation

After Effects

Images Courtesy of: ACM – SIGGRAPH and ECCV; Xue Bai

Jue Wang; David Simons; Adobe

Problem: Interactive Video Segmentation

- Pixel level accuracy
- Minimal user intervention
- Interactive real-time

High-Quality Video Object Cutout

Original

Challenges

overlapping color distributions

weak boundaries

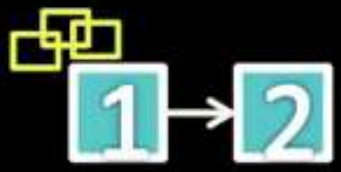
topology changes, dynamic backgrounds

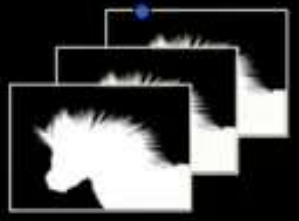
Features

- Accuracy
  work with complicated scenes
- Robustness
  on diverse data
- Practical workflow
  easy to converge/interact
- Computational efficiency
  Faster than 2 frames per second

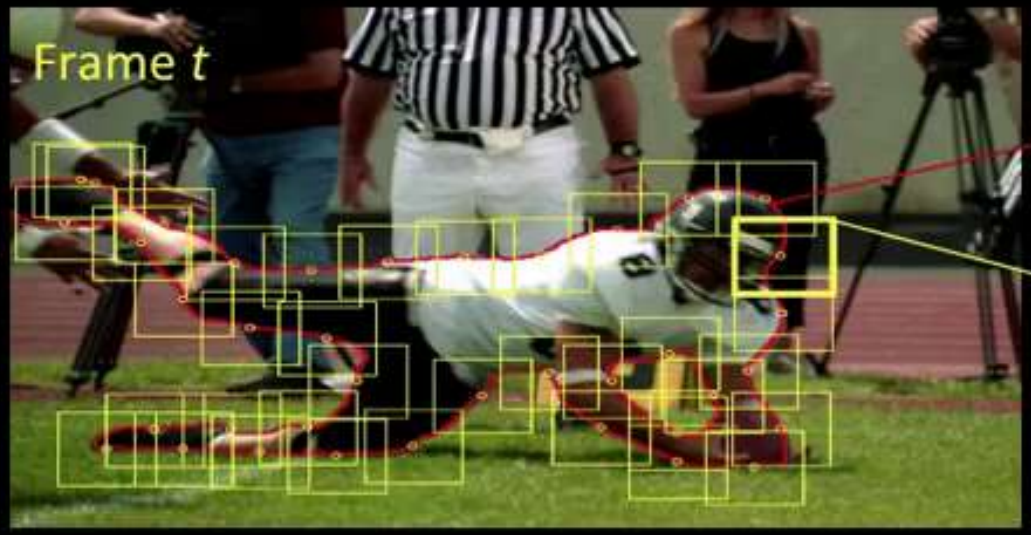
Algorithm Overview

- Localized classifiers
- Multi-frame propagation
- Local correction
- Post-processing

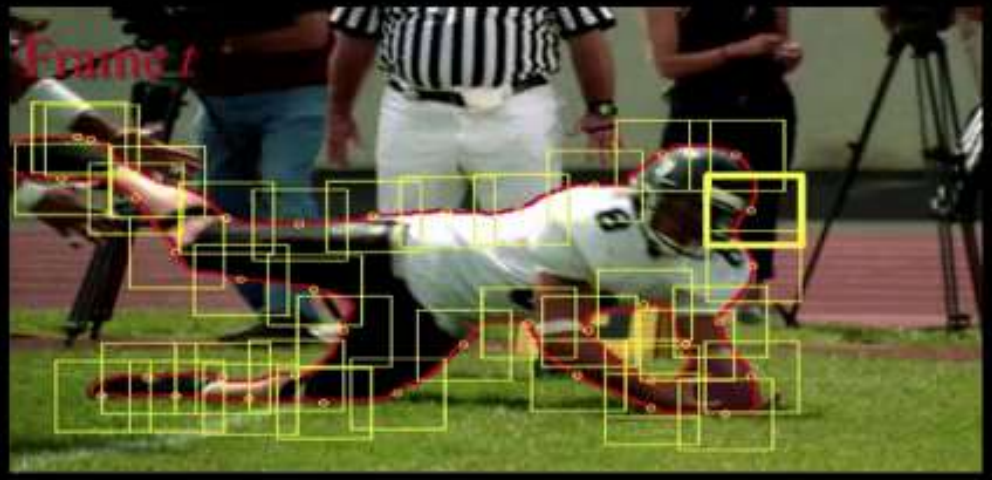




Localized Classifiers



Localized Classifiers



Graph cut

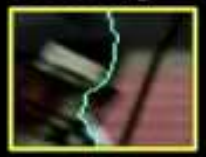
training

shape

GMM's

Frame t+1

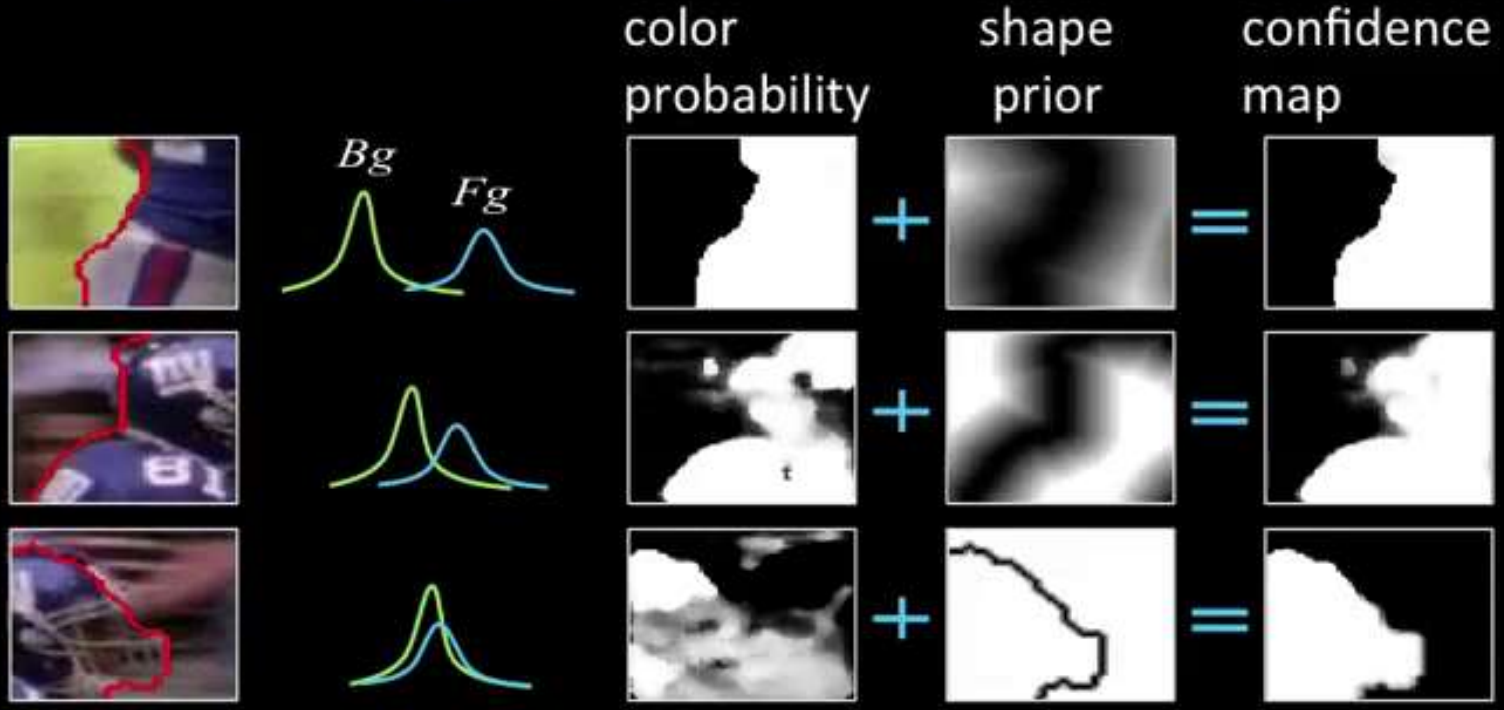
testing



Integration

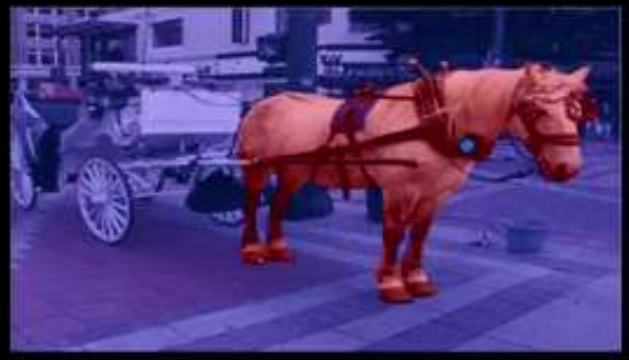
Adaptive Color-Shape Integration

- If colors are separable, trust color model
- If not, trust shape prior



Single-Frame Propagation Example

frame *t* (segmented)



frame *t+1*

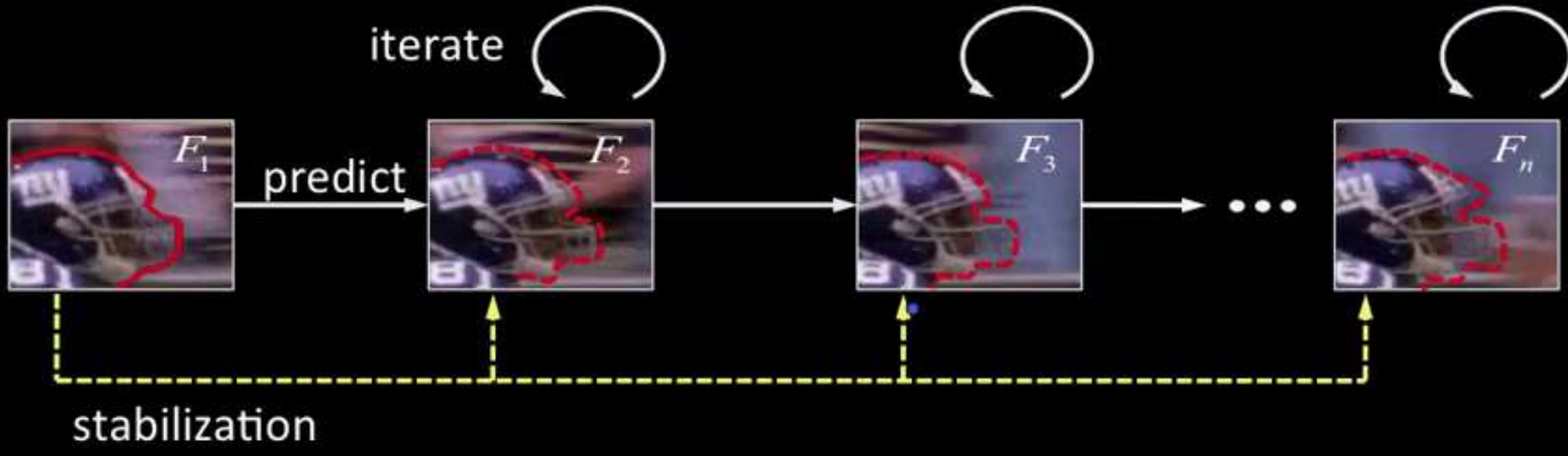
global color model

local color models

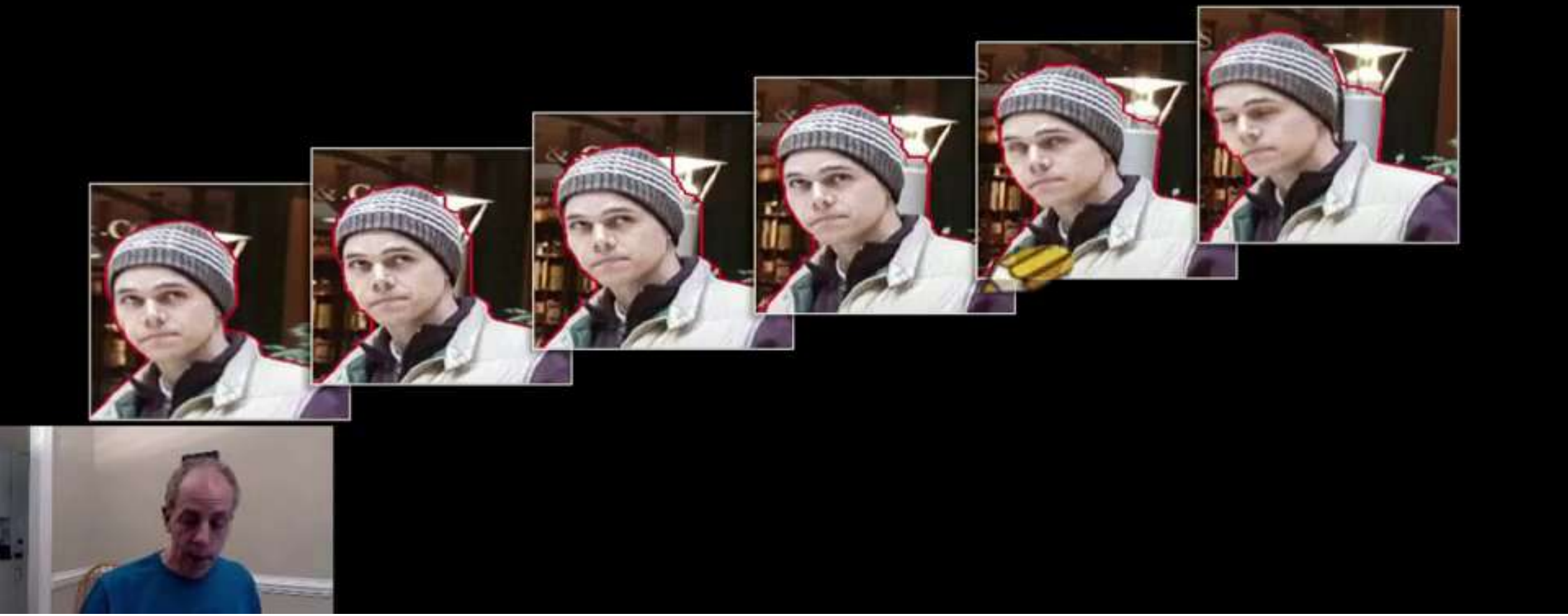
local color models +
local shape prior

Multi-Frame Propagation

- Practical workflow
- Stabilization



Spatial-Temporal Local Correction



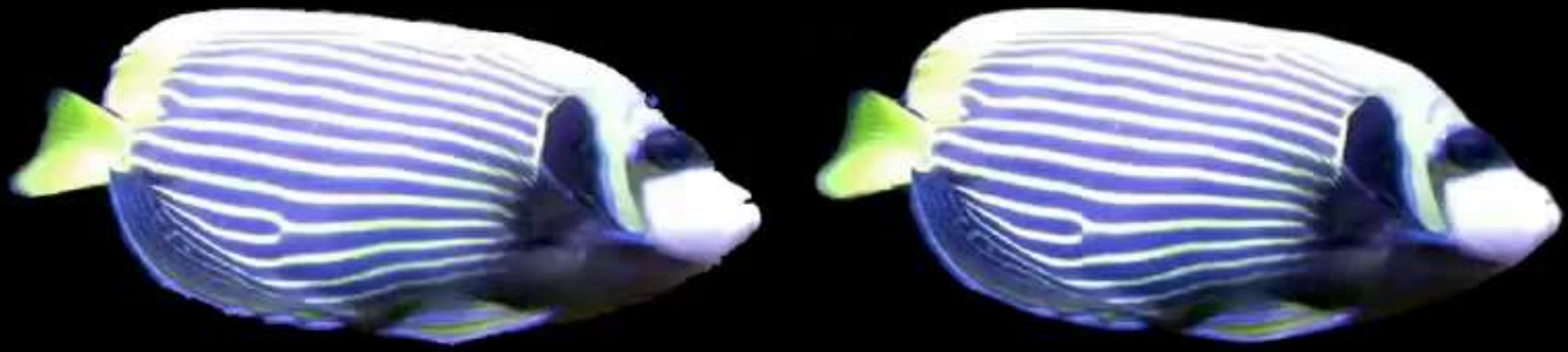
Spatial-Temporal Local Correction

Spatial-Temporal Local Correction

Affects only a few local windows

Propagates changes temporally

Post-processing



before

after

Results

720×406 185 frames

Results

720×576 50 frames

Results

848×480 232 frames

original

filter

relight

composite

Original

Composite

473×588

Original

Composite

504×380