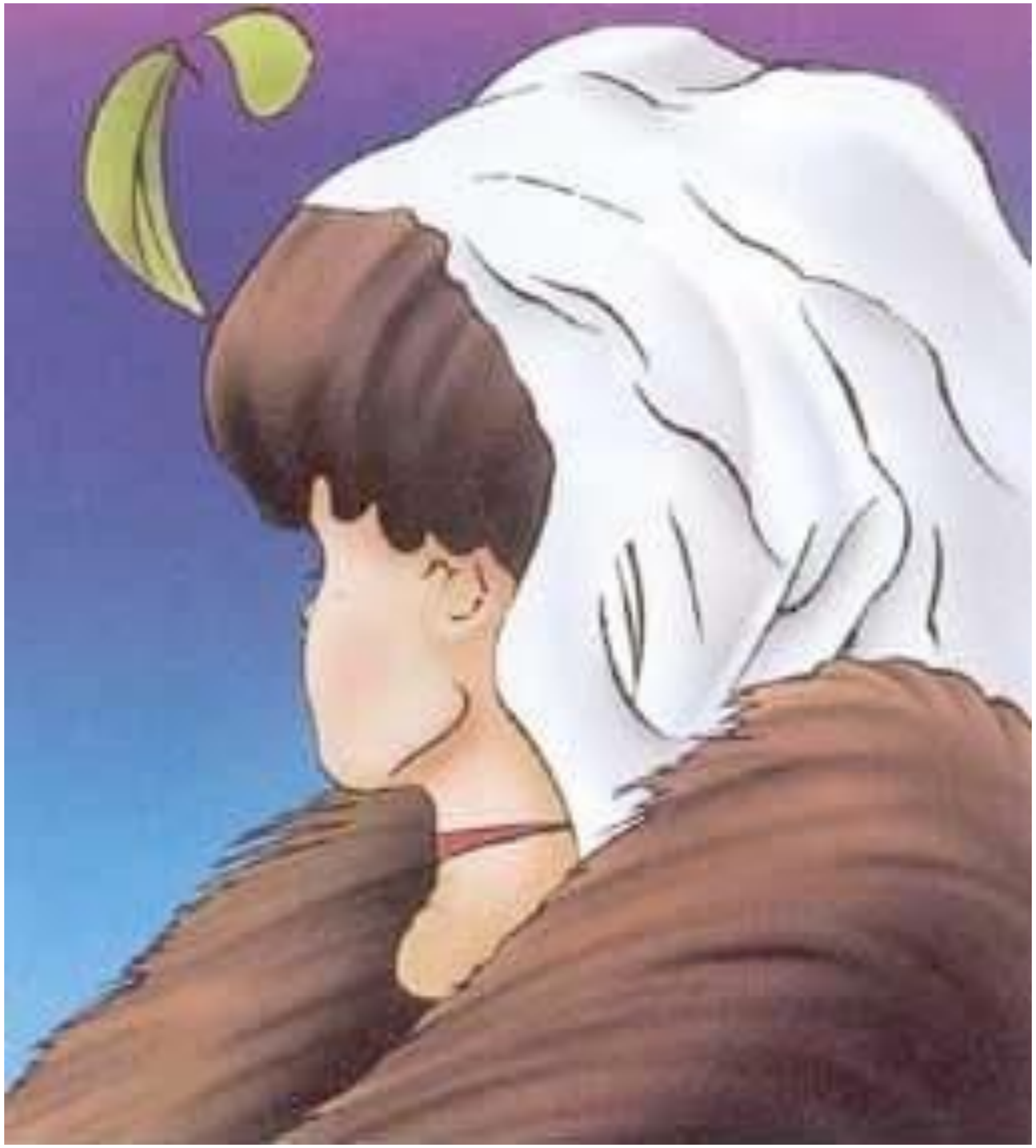
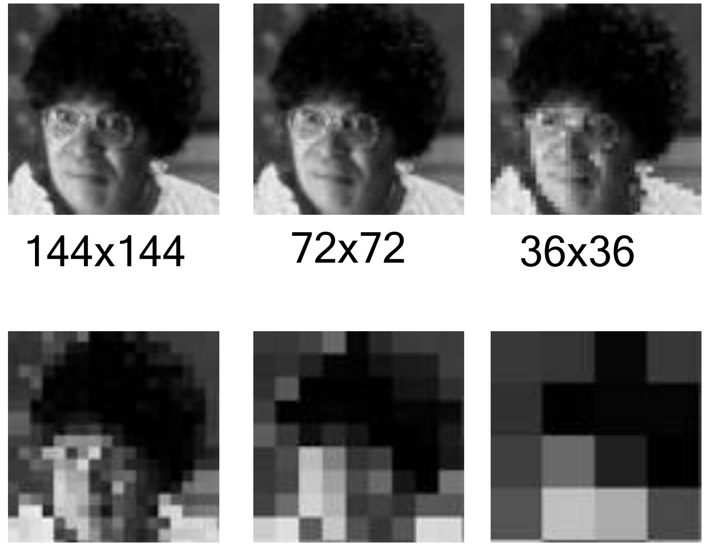
Image Segmentation



Remember:

- Samples not just squares
- Sensors introduce noise
- Quantization can hurt
- Questions?

Geometric resolution



144x144 72x72 36x36

18x18 9x9 4x4

A Pixel Is *Not* A Little Square,
A Pixel Is *Not* A Little Square,
A Pixel Is *Not* A Little Square!
(And a Voxel is *Not* a Little Cube)

Overview

What is image segmentation?

Types of segmentation algorithms

1. Thresholding, region labelling and growing algorithms
   – (connected components, region growing, watershed)
2. Statistical Segmentation
   – (k-means, mean shift)
3. Graph based methods
   – (Merging algorithms, splitting algorithms, split/merge)
4. Edge based methods
   – (Intelligent Scissors, Snakes)

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What is Image Segmentation?

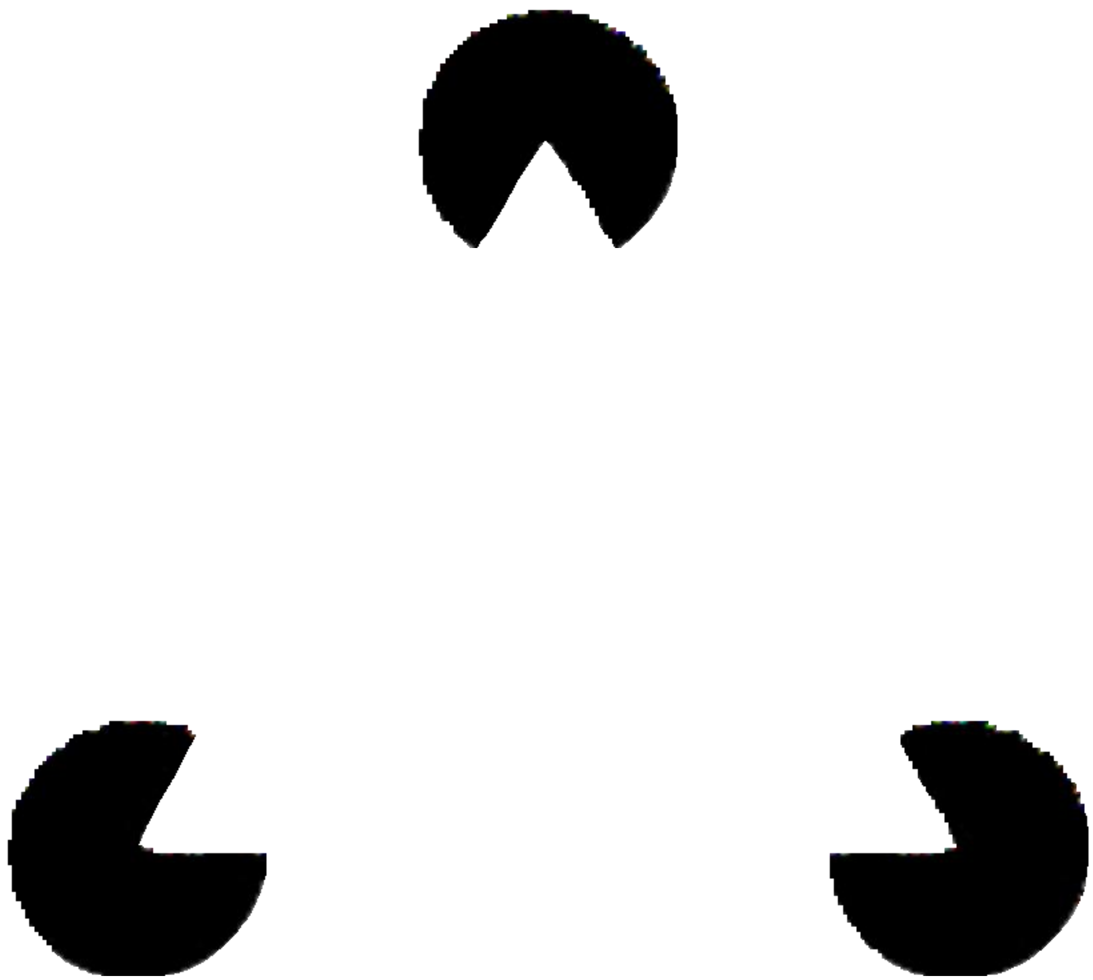
- Segmentation partitions an image into regions of interest (ROI).
- The first stage in many automatic image analysis systems.
- A *complete segmentation* of an image *I* is a finite set of non--overlapping regions $R_1, \ldots, R_N$, such that

$$I = \bigcup_{i=1}^{N} R_i \text{ and } R_i \cap R_j = \phi \ \forall\, i \neq j.$$

Where is the ...?

[Emerging Images, Mitra et al., Siggraph Asia, 2009]

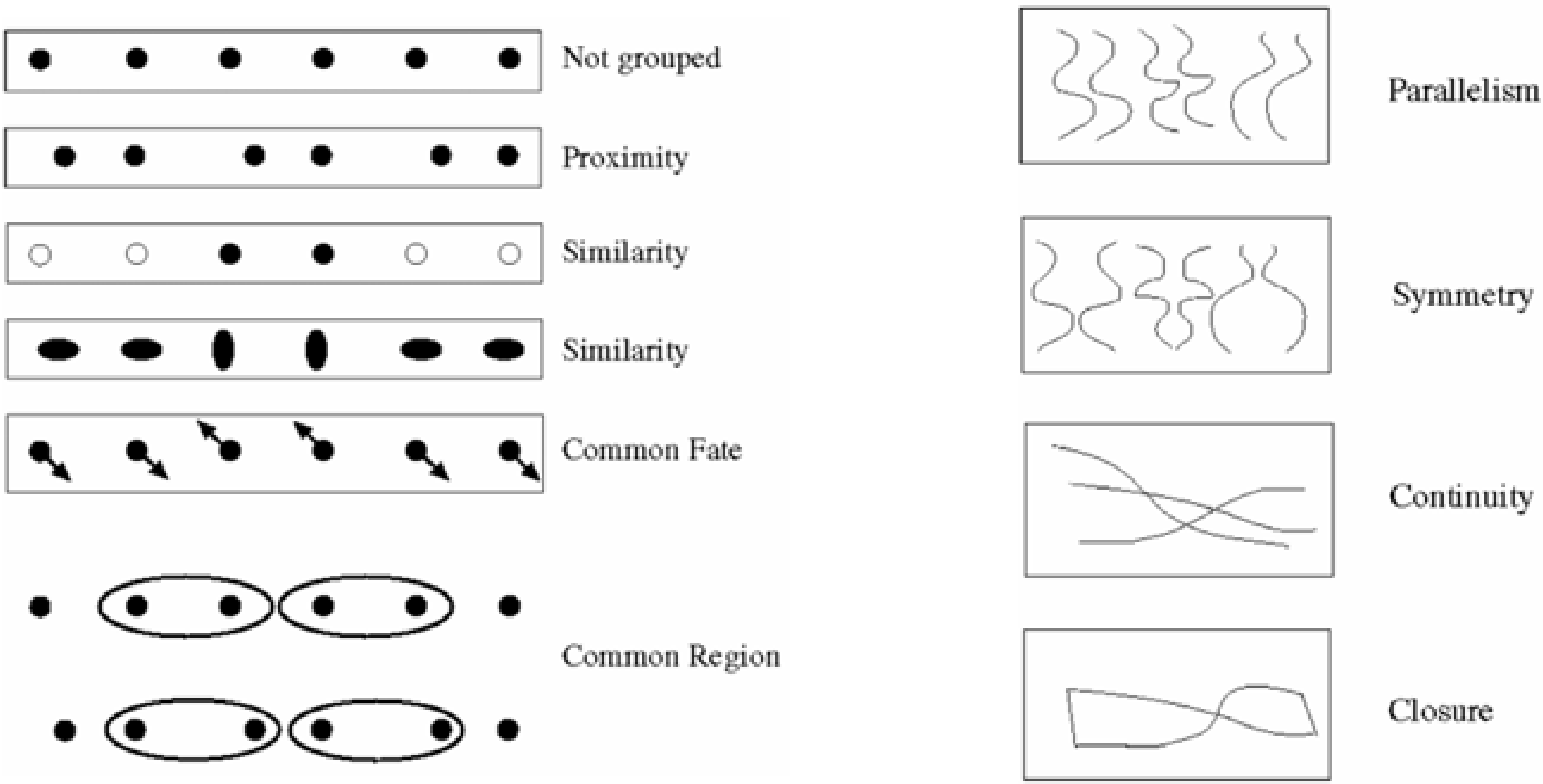
Kanizsa Triangle



Illusory Contours: Kanizsa, G. (1955), Rivista di Psicologia 49(1): 7-30

The Cup?

Gestalt Factors

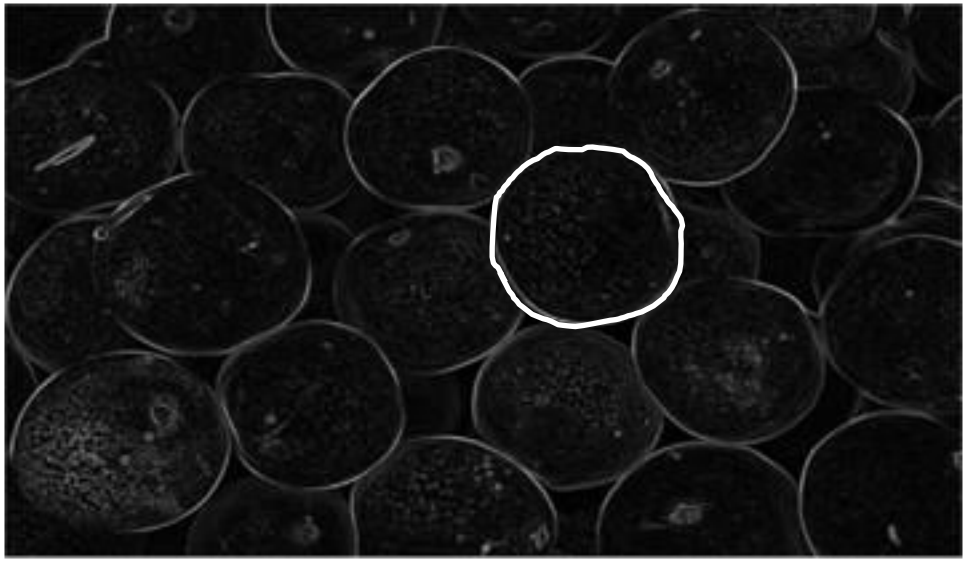


These factors make intuitive sense, but are very difficult to realize algorithmically

Slide from S.Lazebnik

color

texture

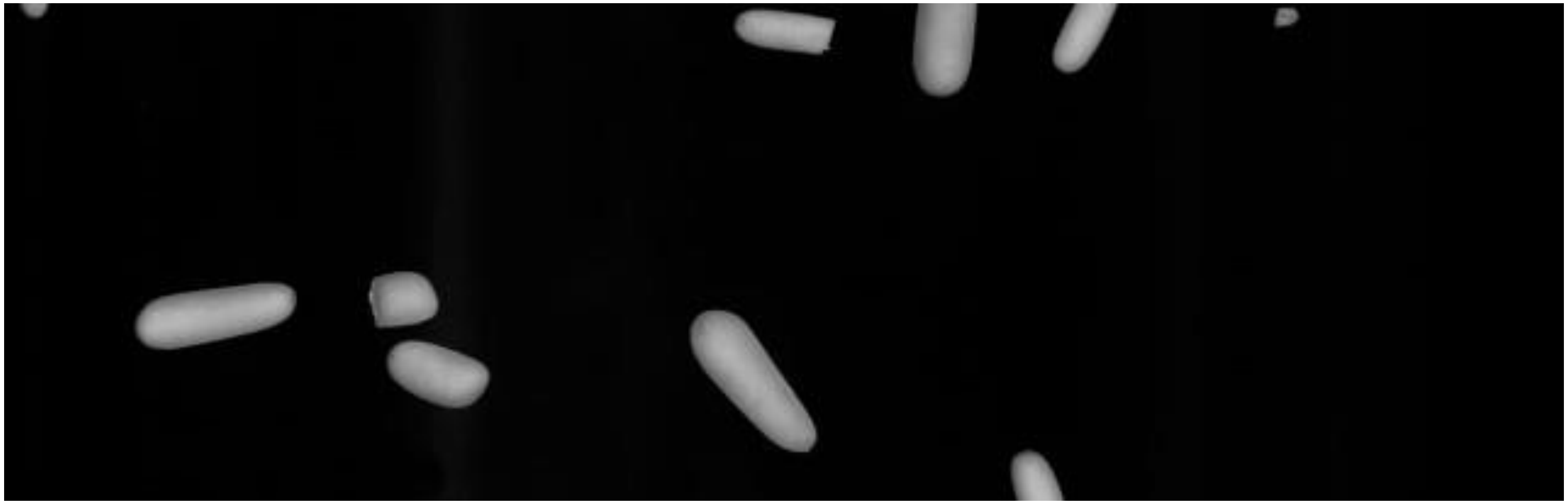


gradient

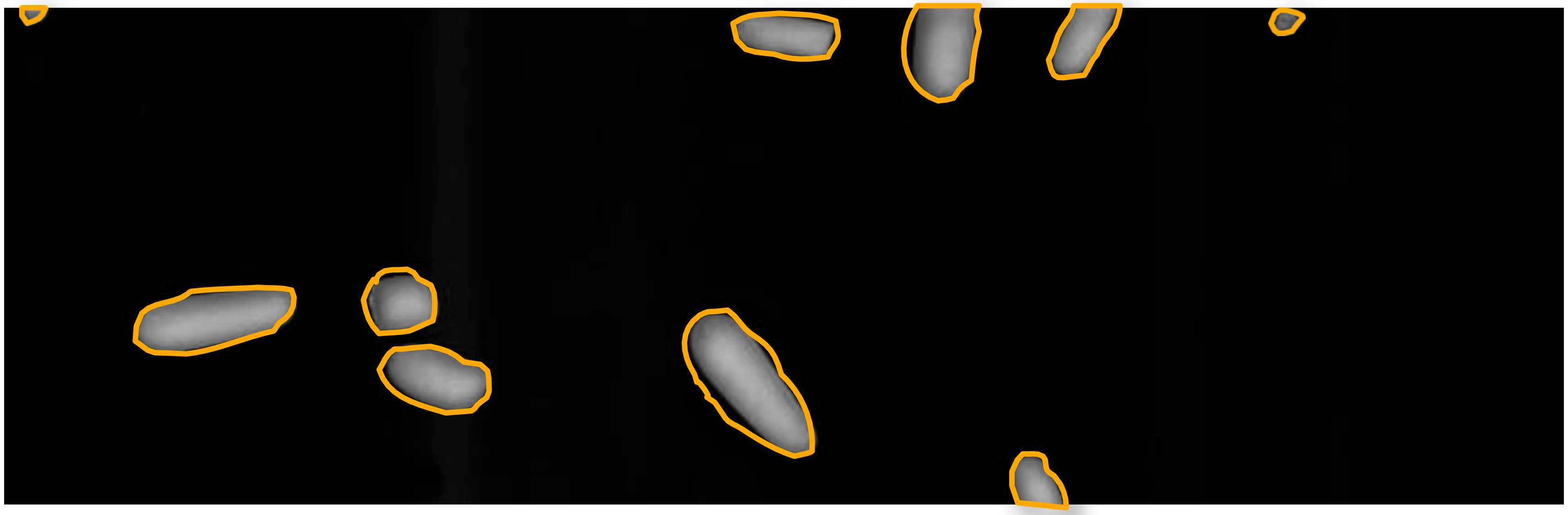
http://vision.ece.ucsb.edu/segmentation

Combinations… 20+

How to Segment?



How to Segment?

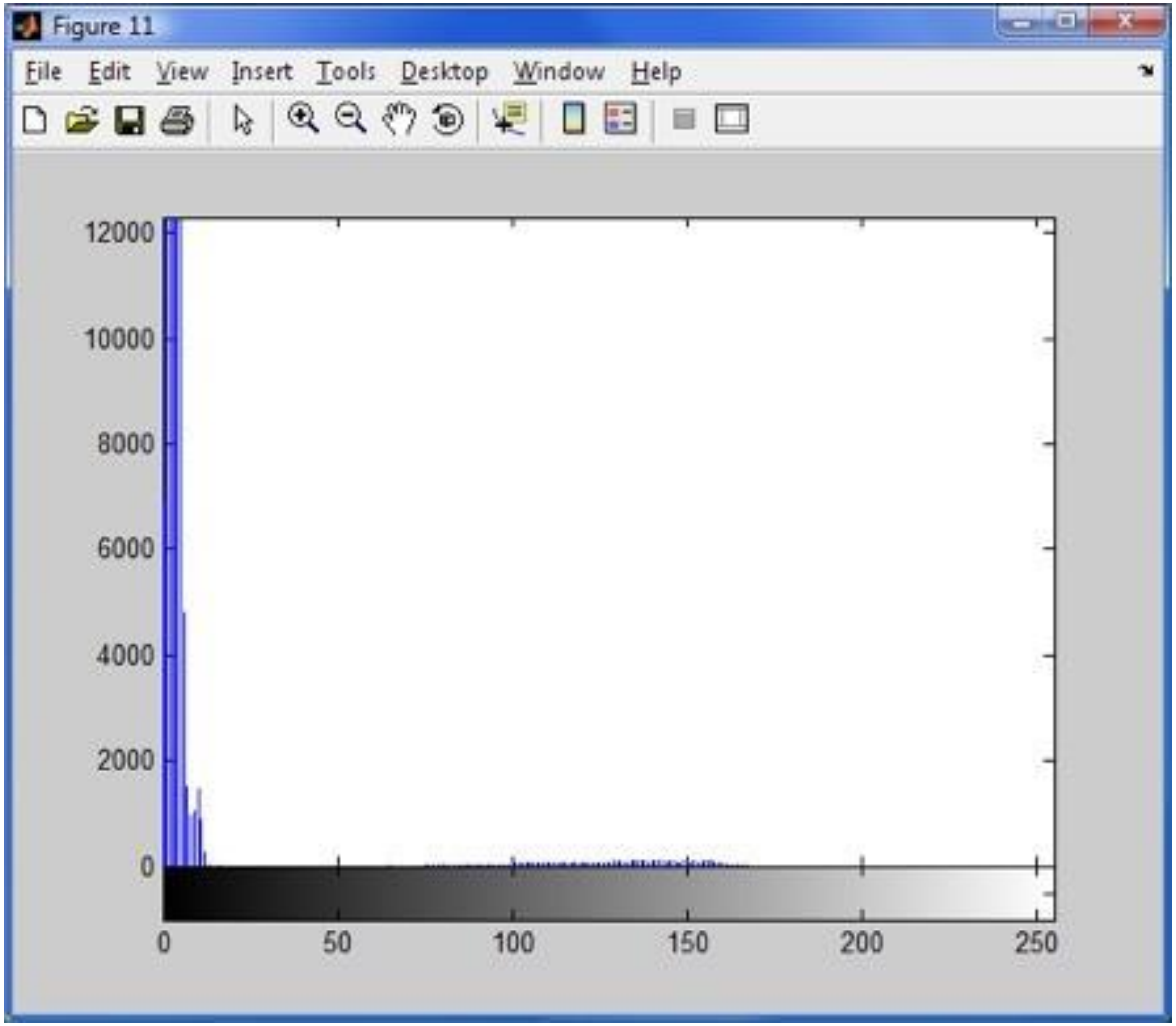


Exclude Dark Pixels?

```
I = imread('BlobsIP.png');
figure;
imshow( I )
size(I)          --> [ 244   767  3 ]
figure;
imhist( I(:,:,1) )
figure;
imshow( I(:,:,1) > 20 )
```

Histogram

pixels

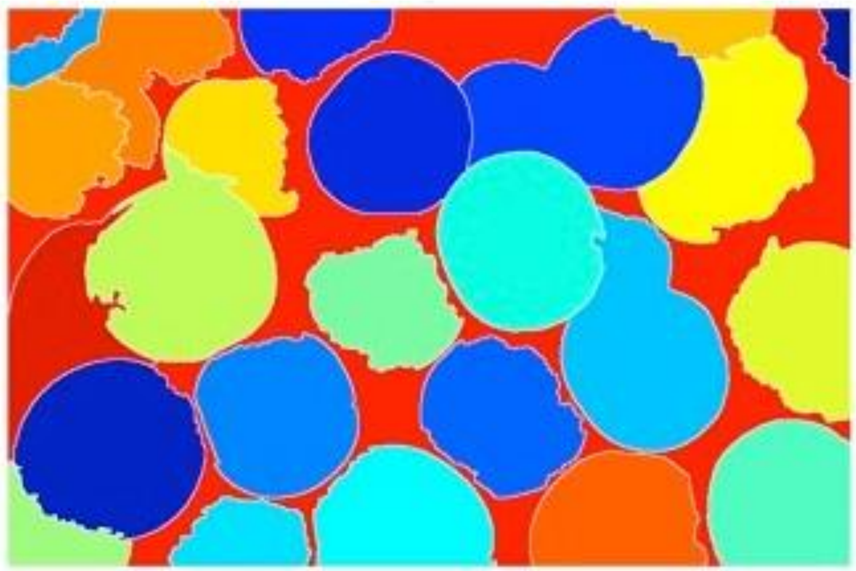


gray-levels [0,255]

Harder Example

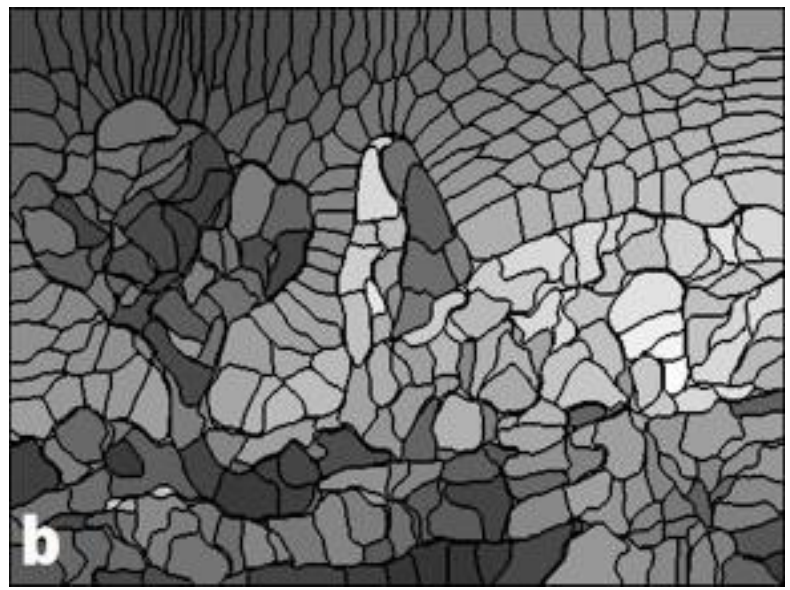
Segmentation Philosophies

Binary vs. Multi--label



Supervised vs Unsupervised

Exact vs. Oversegmented

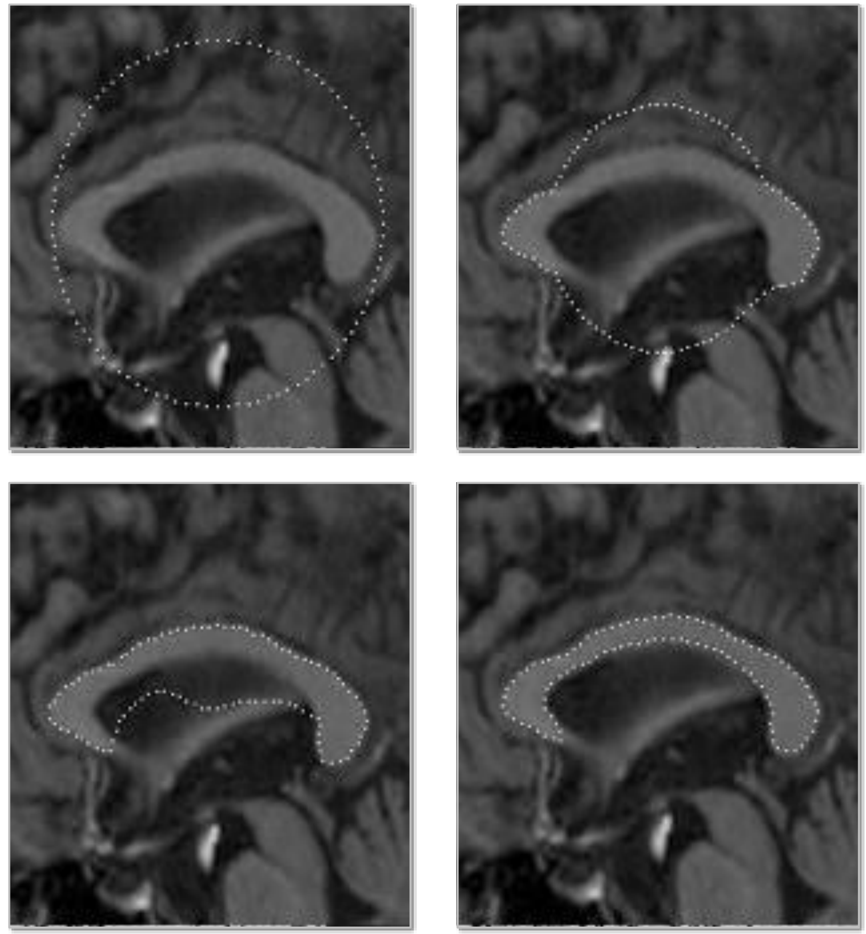


Topdown vs. Bottomup

... they lie on the same object ... they are locally coherent

Boundary-vs. Pixel-based

Pixel- Based



Edge- Based
(e.g., Snakes/Active Contours)

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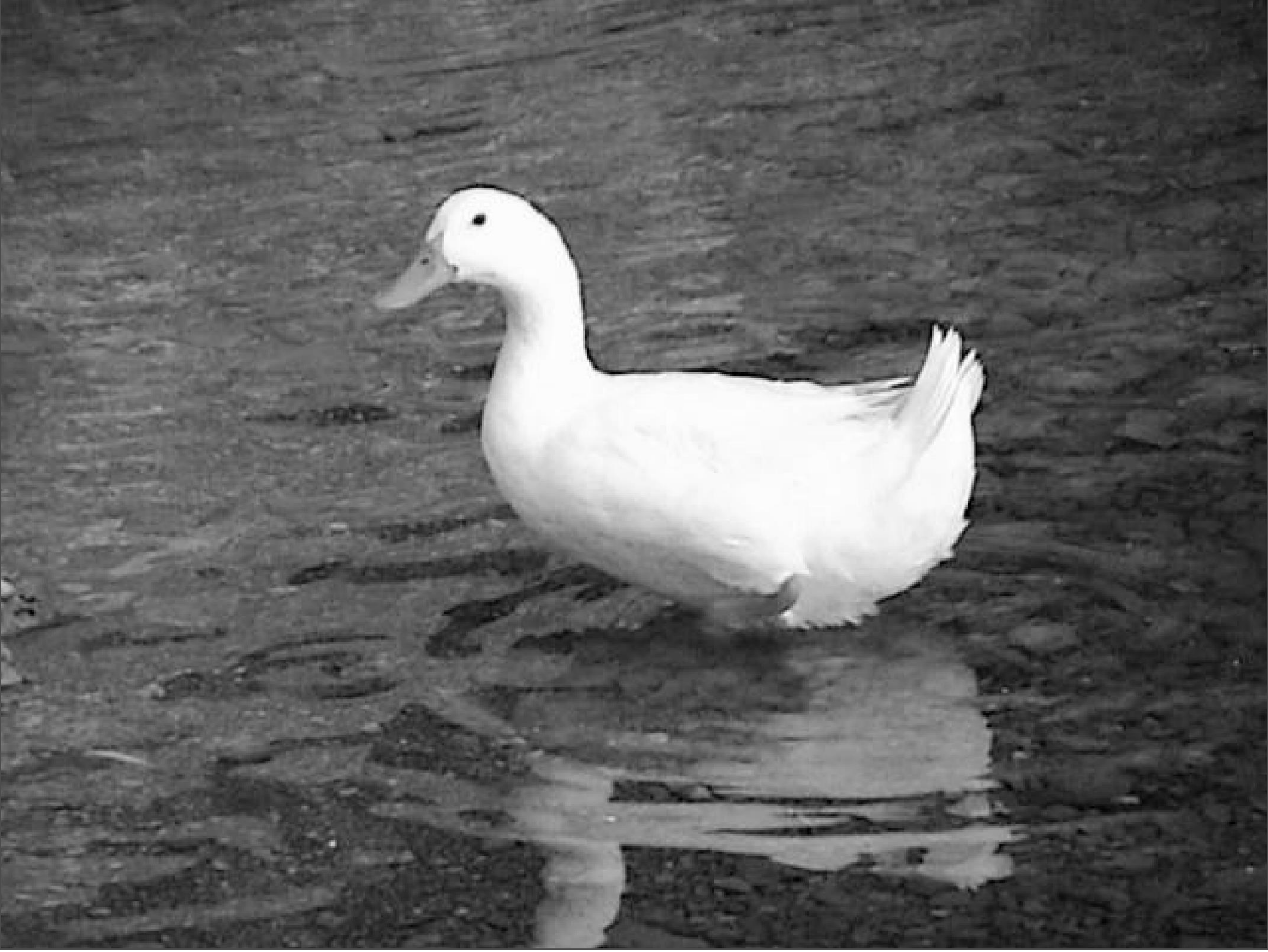
Thresholding

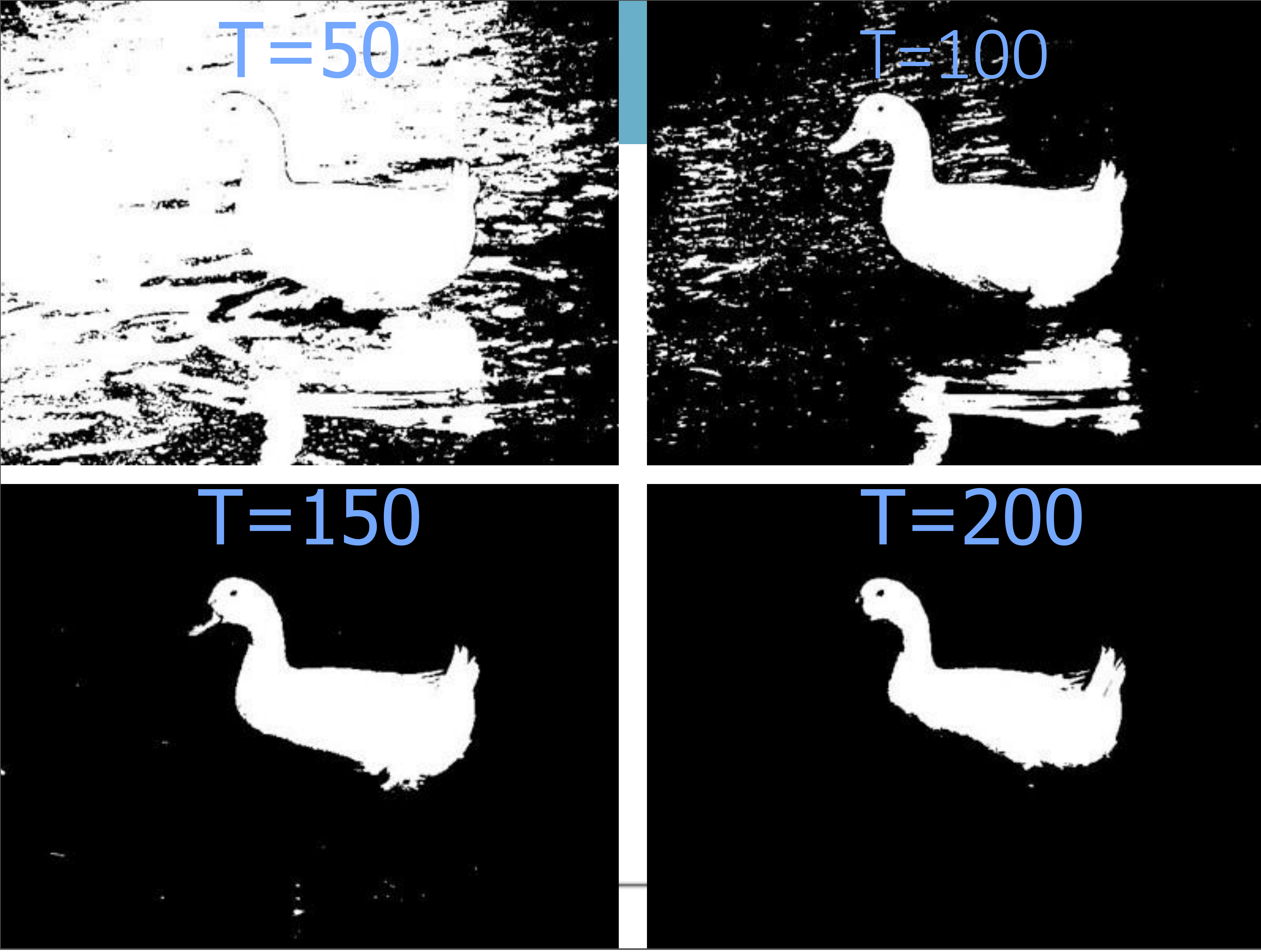
- Thresholding is a simple segmentation process.
- Thresholding produces a binary image *B*.
- It labels each pixel **in** or **out** of the region of interest by comparison of the greylevel with a threshold *T*:

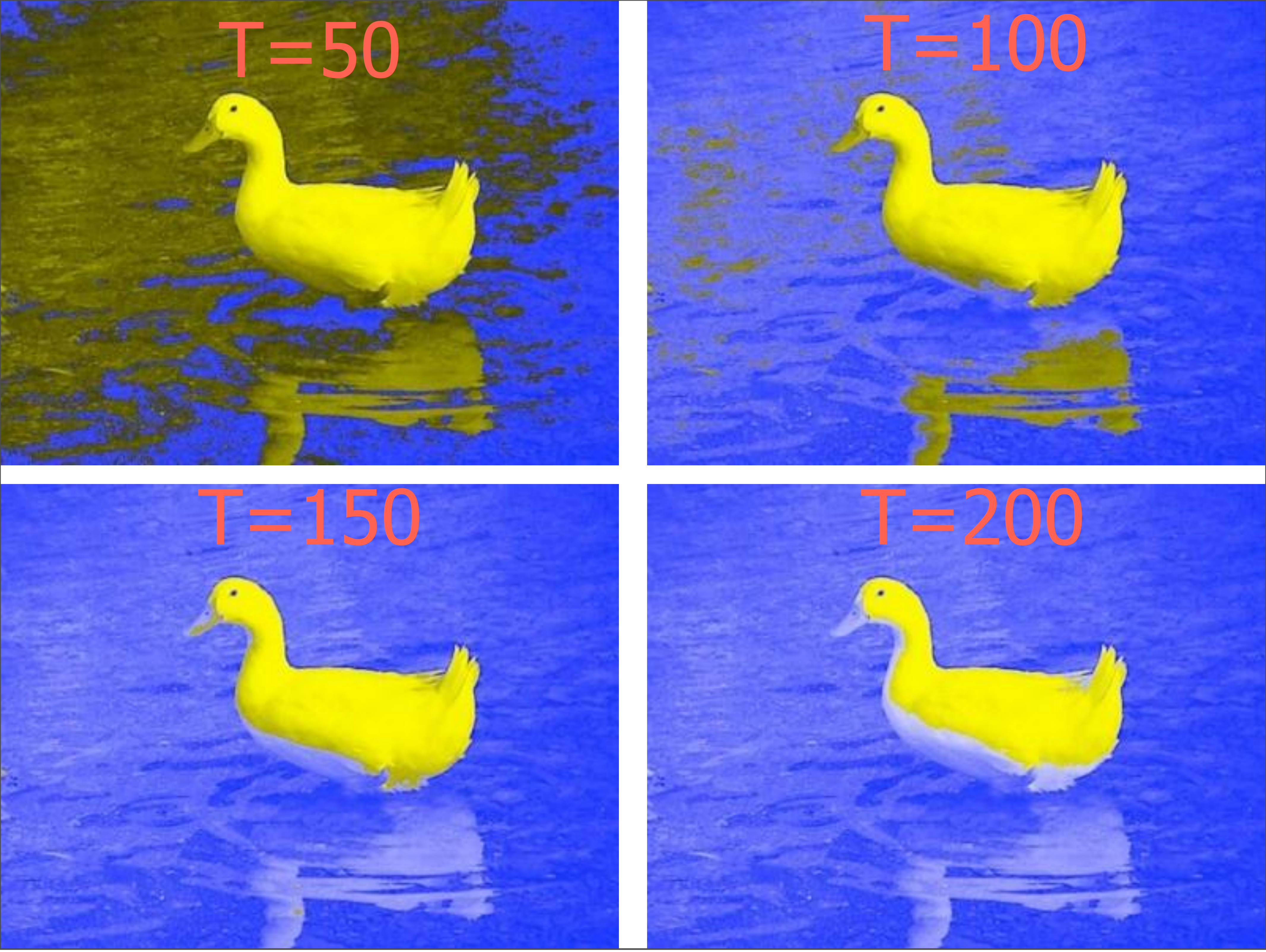
$$
B(x,y) = \begin{cases} 1 & \text{if } I(x,y) \ge T \\ 0 & \text{if } I(x,y) < T. \end{cases}
$$

Basic Thresholding Algorithm

```
for x=1:X
    for y=1:Y
        B(x,y) = (I(x,y) >= T);
    end
end
```

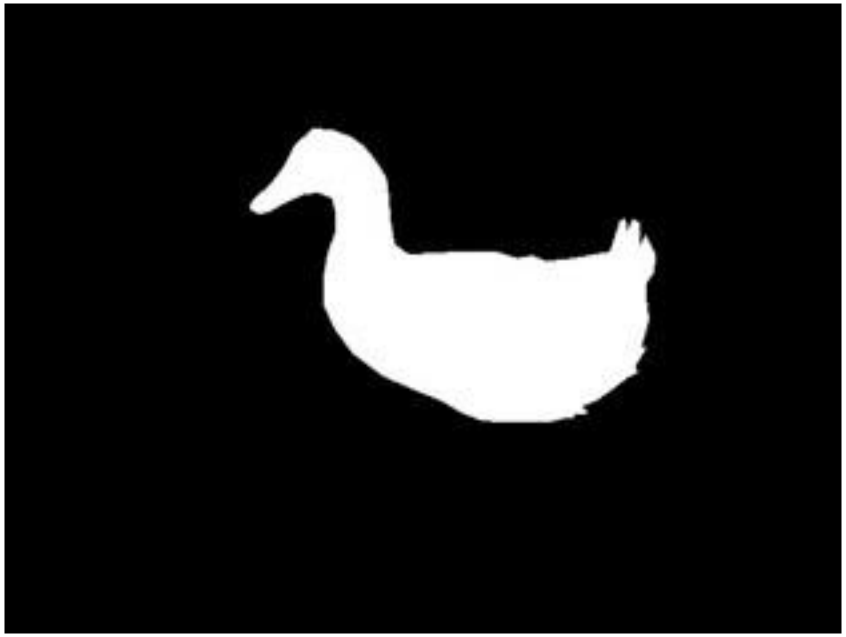



T=50
T=100
T=150
T=200


T=50
T=100
T=150
T=200

Segmentation Performance

- To analyze performance, we need to know the true classification of each test.
- We need to do the segmentation by hand on some example images.



ground truth

ROC Curve

- An ROC (receiver operating characteristic) curve characterizes the performance of a binary classifier.

- A binary classifier distinguishes between two different types of thing, e.g.,
    - Healthy/afflicted patients – cancer screening
    - Pregnancy tests
    - Foreground/background image pixels
    - Object detection

Classification Error

- Binary classifiers make errors.
- Two types of input to a binary classifier:
  - Positives
  - Negatives
- Four possible outcomes in any test:

True positive	False negative	} P: Total # positives
True negative	False positive	} N: Total # negatives

Classified: correctly | incorrectly

ROC Explained

predicted		ground truth: P	ground truth: N
	P'	TP	FP
	N'	FN	TN

ROC Explained

ground truth

		P	N
predicted	P’	TP	FP
	N’	FN	TN

$$TPR = TP/P = TP/(TP+FN)$$

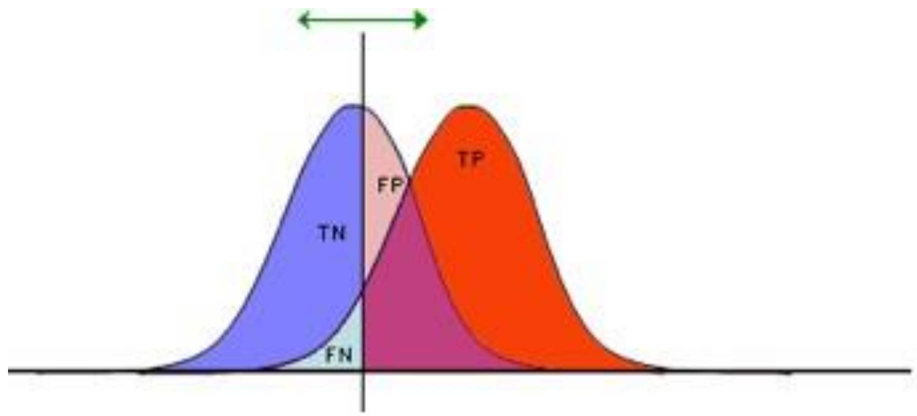
ROC Explained

		ground truth	
		P	N
predicted	P'	TP	FP
	N'	FN	TN

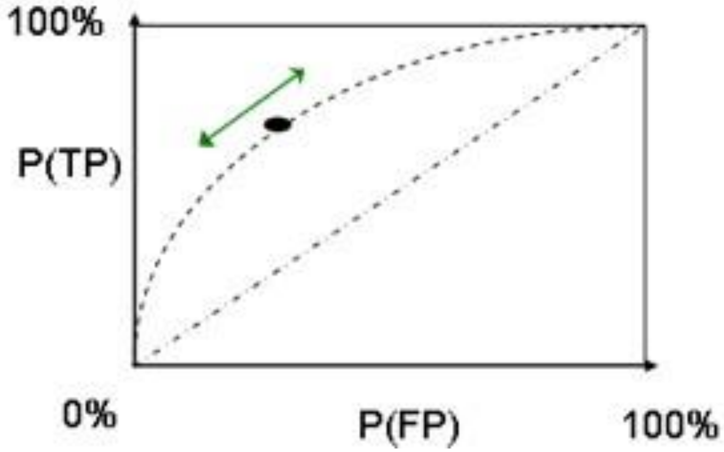
$$TPR = TP/P = TP/(TP+FN)$$

$$FPR = FP/N = FP/(FP+TN)$$

ROC Curve

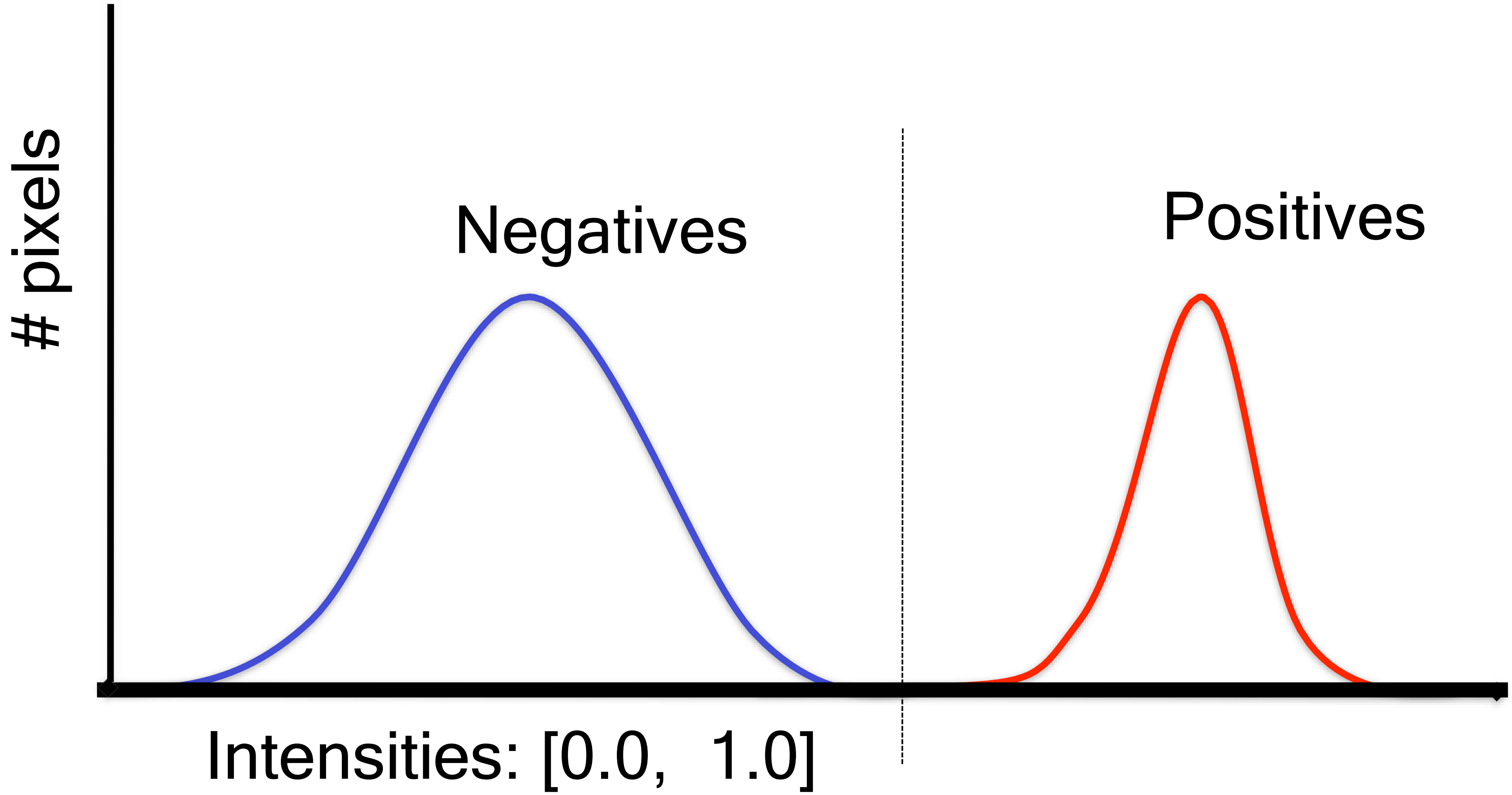


TP	FP
FN	TN
1	1

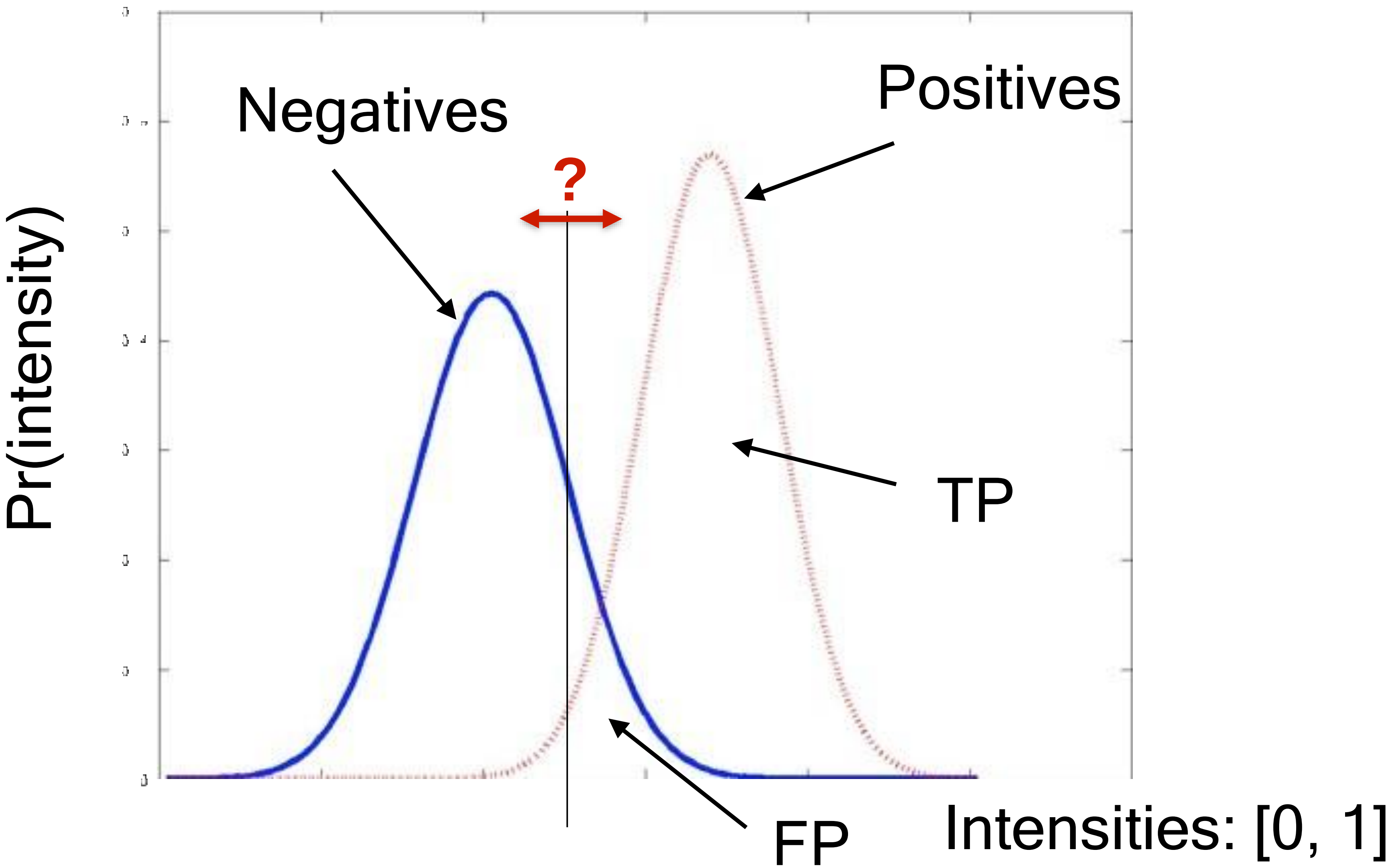


[wikipedia]

Wouldn't it be nice…



Real Measurement Distributions



Classification Outcomes

- As we change the threshold, FP and TP change.
- Notice that:
  - FP + TN = N (the total number of negatives)
  - TP + FN = P (total positives)

- How to evaluate performance?

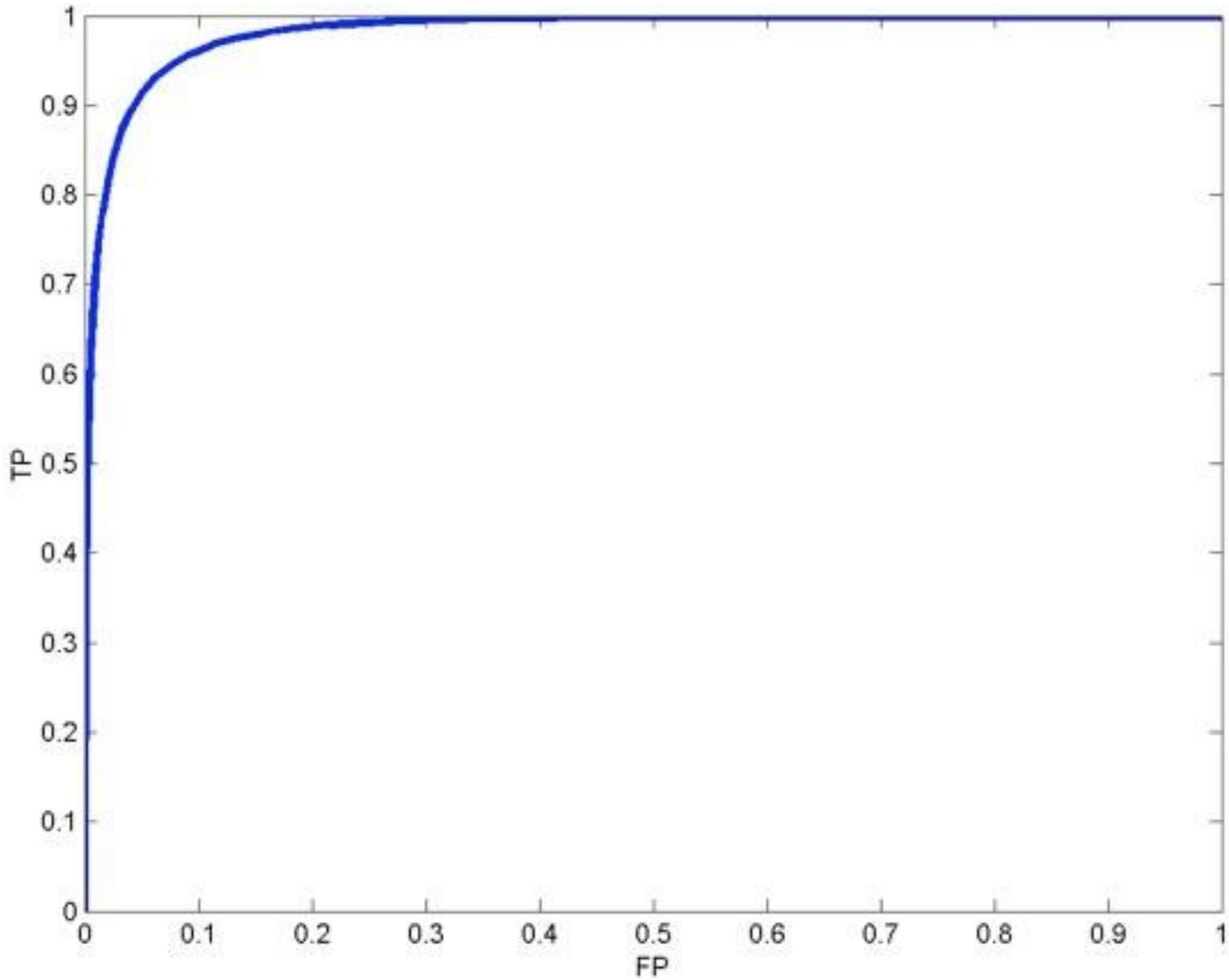
The ROC Curve

- Characterizes the error trade-off in binary classification tasks.
- It plots the TP fraction against FP fraction.

- TP fraction (*sensitivity*) is $\frac{\text{True positive count}}{P}$

- FP fraction (1-*specificity*) is $\frac{\text{False positive count}}{N}$

$$\left[\frac{\text{(True positive count)}}{P = TP + FN}\right]$$

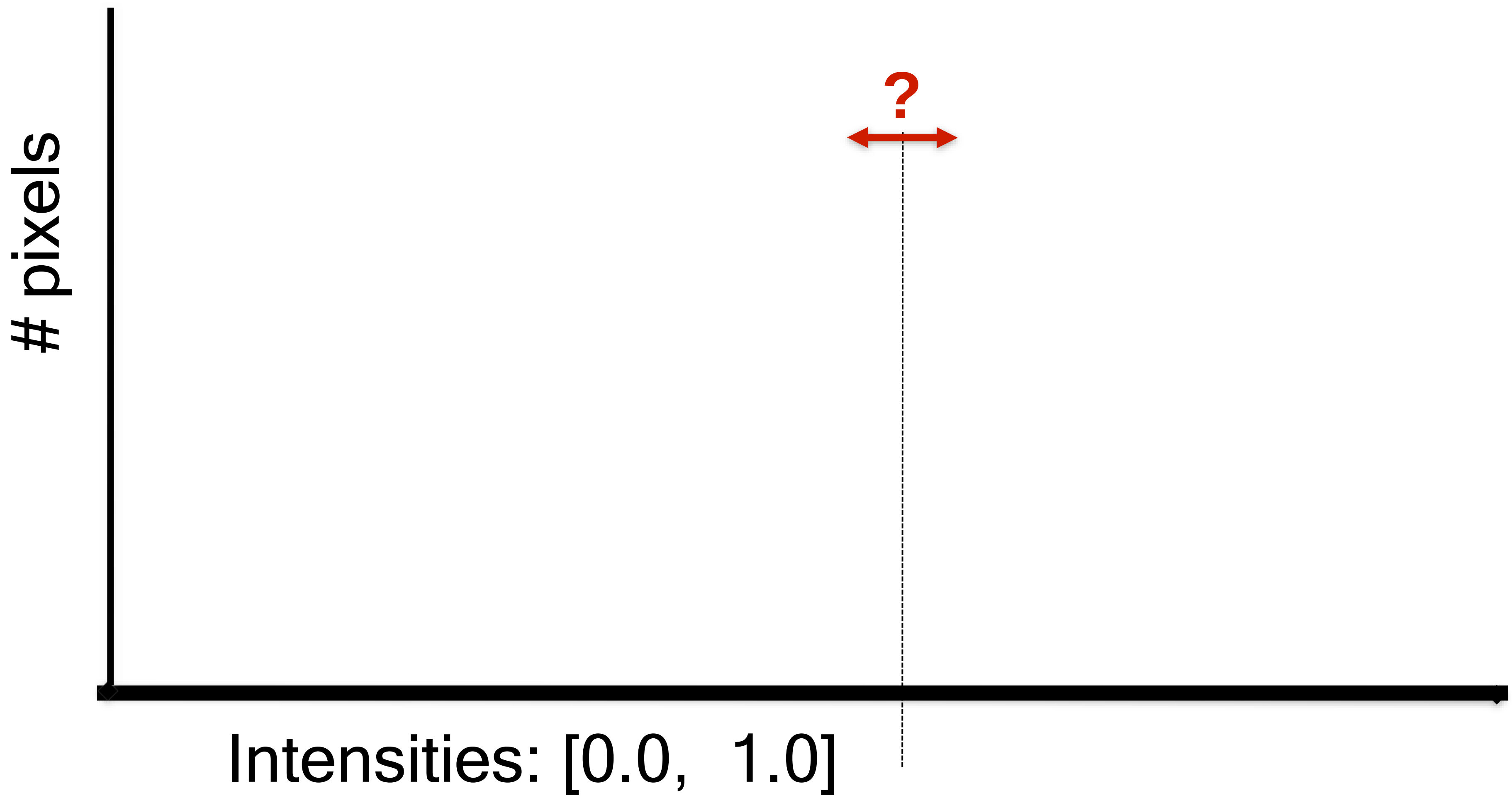


$$\left[\frac{\text{(False positive count)}}{N = FP + TN}\right]$$

Properties of ROC curves

- An ROC curve always passes through (0,0) and (1,1).
- What is the ROC curve of a perfect system?
- What if the ROC curve is a straight line from (0,0) to (1,1)?

How to select a threshold?



Operating points

- Choose an *operating point* by assigning relative costs and values to each outcome:
  - V_{TN} - value of true negative
  - V_{TP} - value of true positive
  - C_{FN} - cost of false negative
  - C_{FP} - cost of false positive
- Choose the point on the ROC curve with **gradient**

$$\beta = \frac{N}{P} \frac{V_{TN} + C_{FP}}{V_{TP} + C_{FN}}$$

- For simplicity, we often set $V_{TN} = V_{TP} = 0$.

Classification outcomes