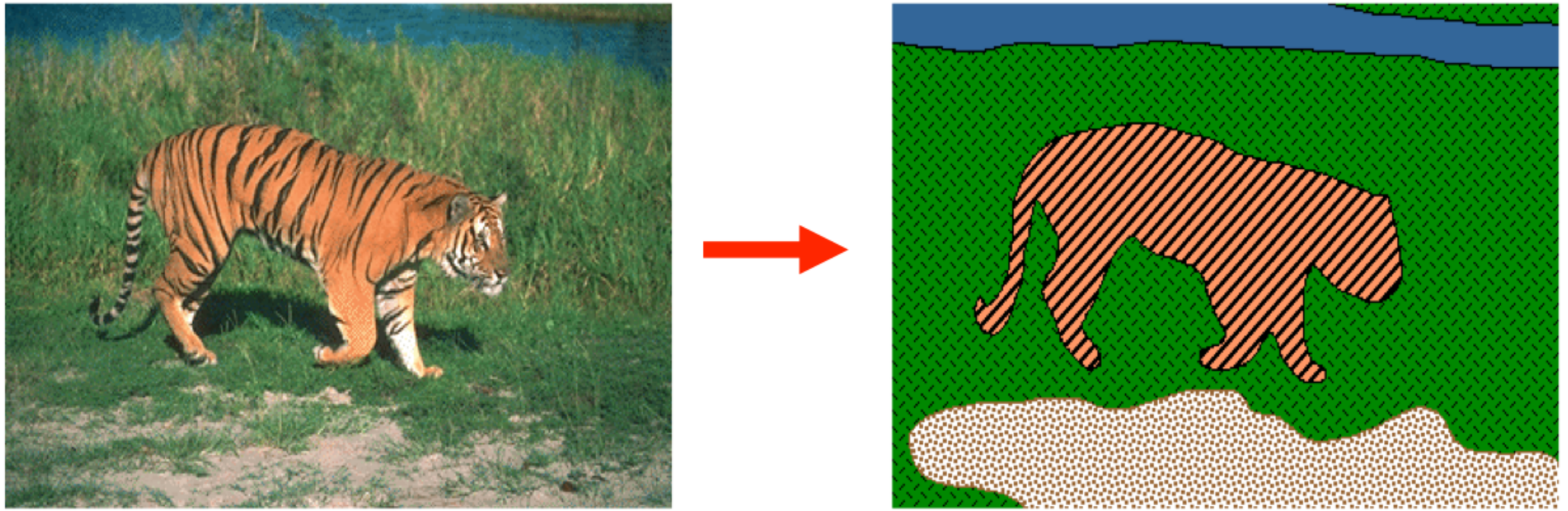
COMP0026: Image Processing

Image Segmentation



UCL

Lectures will be Recorded

Image Segmentation

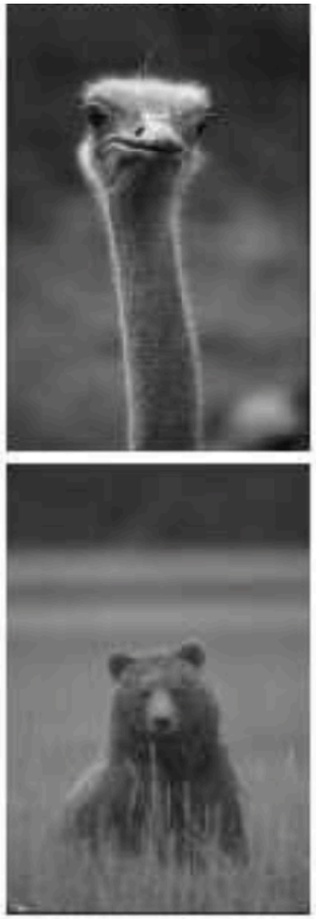


Image Segmentation

Overview

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What is image segmentation?

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Types of segmentation algorithms

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- **Segmentation partitions an image into regions of interest (ROI).**

- **The *first* stage in many automatic image analysis systems.**

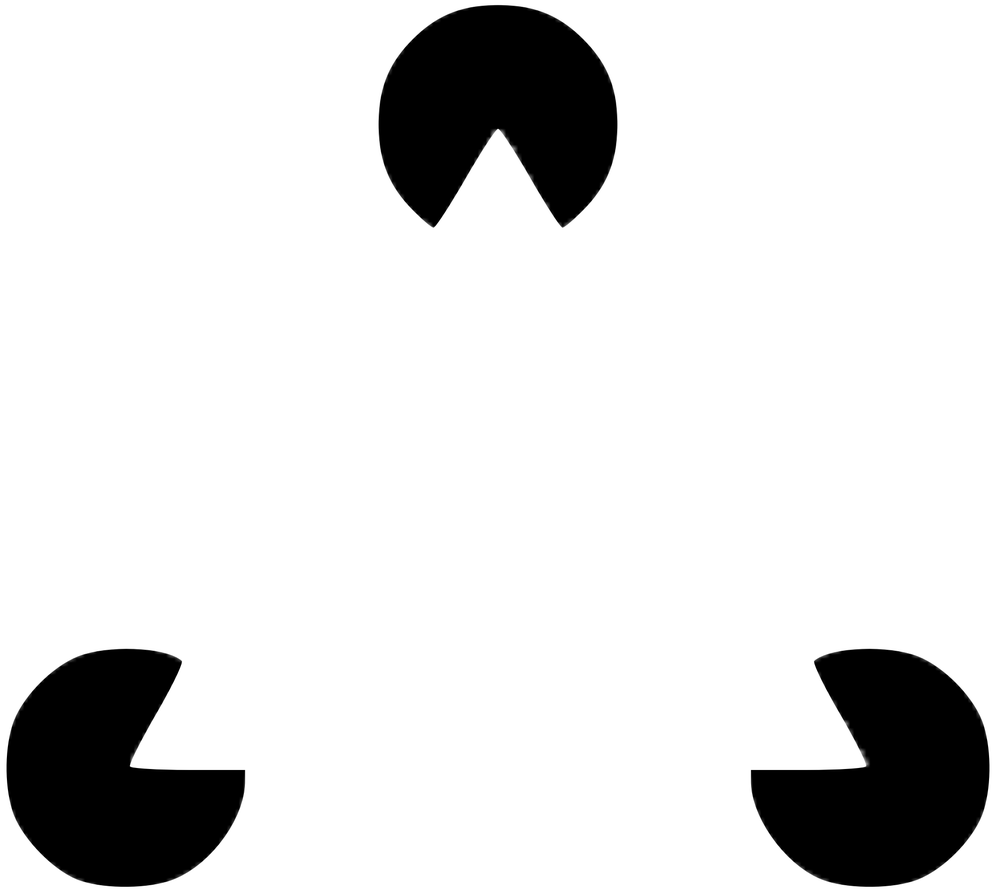
- **A *complete segmentation* of an image *I* is a finite set of non-overlapping regions $R_1, \ldots, R_N$, such that**

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

Where is the …?

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

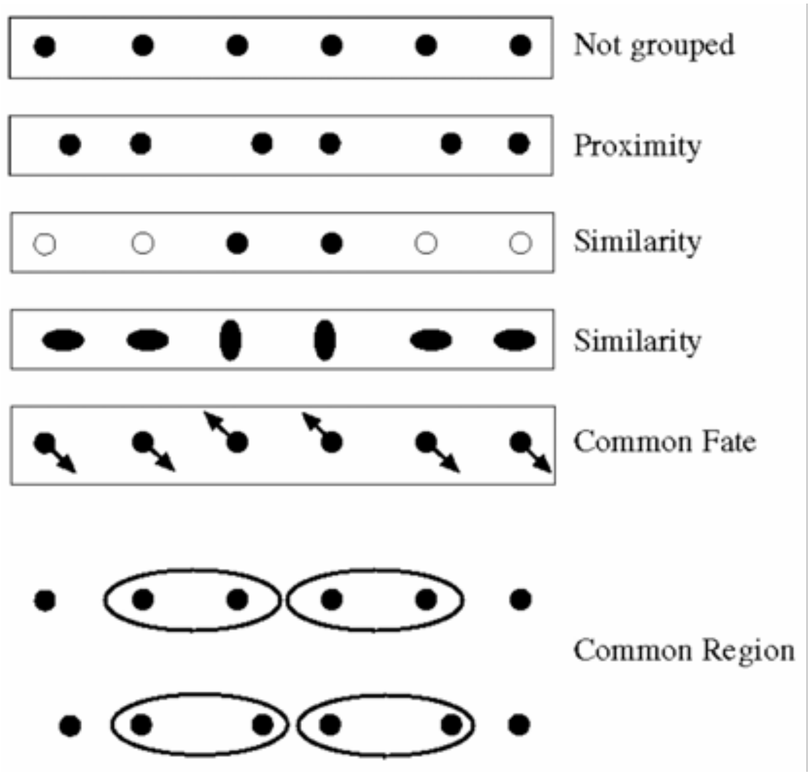
Kanizsa Triangle

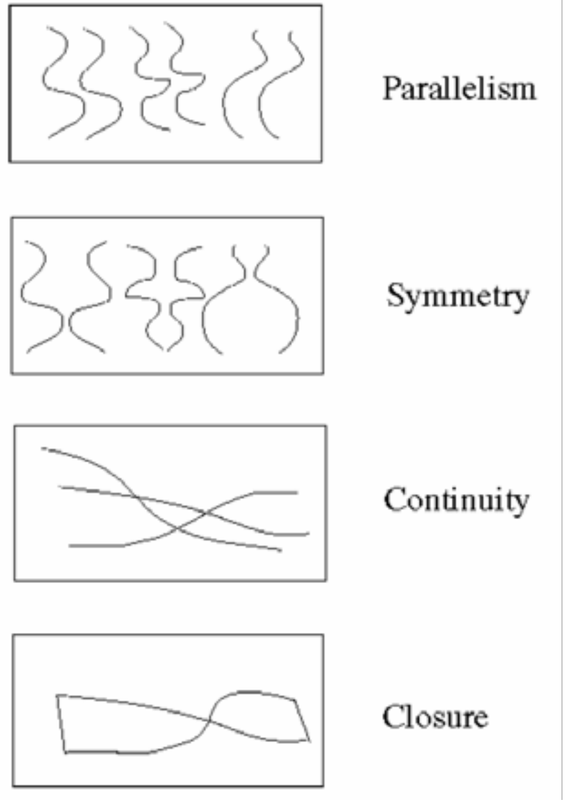


Illusory Contours: Kanizsa, G. (1955), Rivista di Psicologia 49(1): 7–30

The Cup?

Gestalt Factors





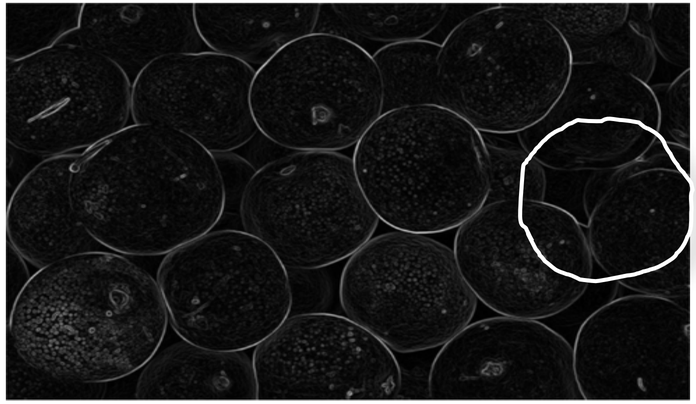
Intuitive sense, but difficult to realize algorithmically.

Slide from S.Lazebnik

Image Attributes

color

texture

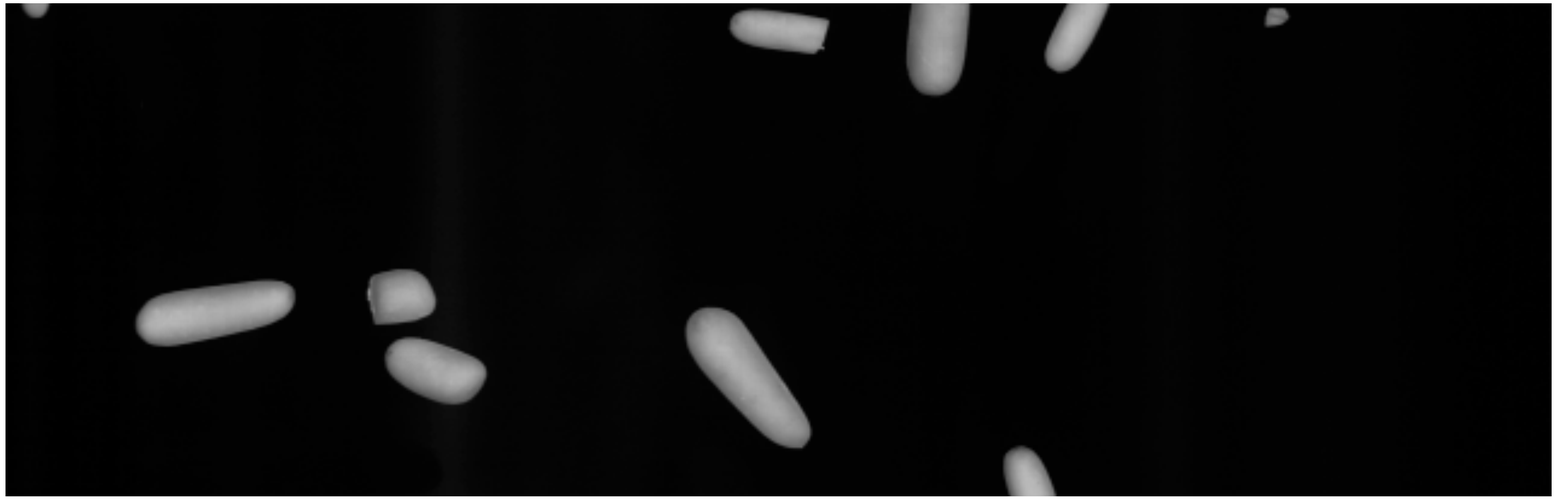


gradient

Combinations

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

How to Segment?



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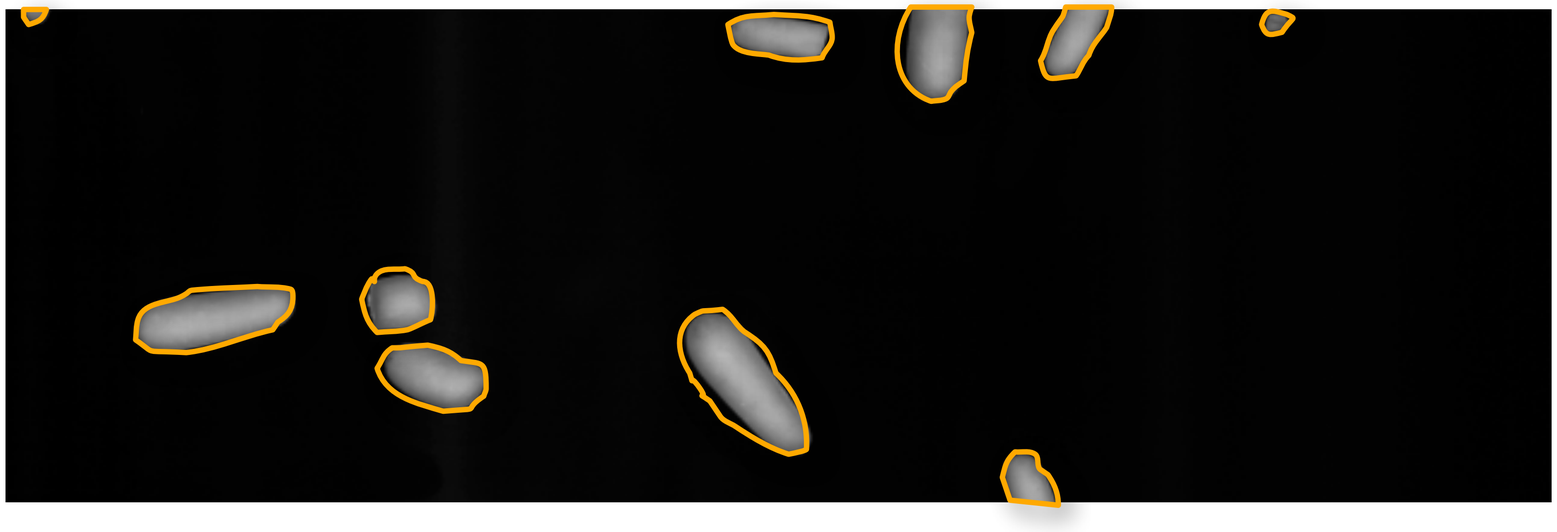
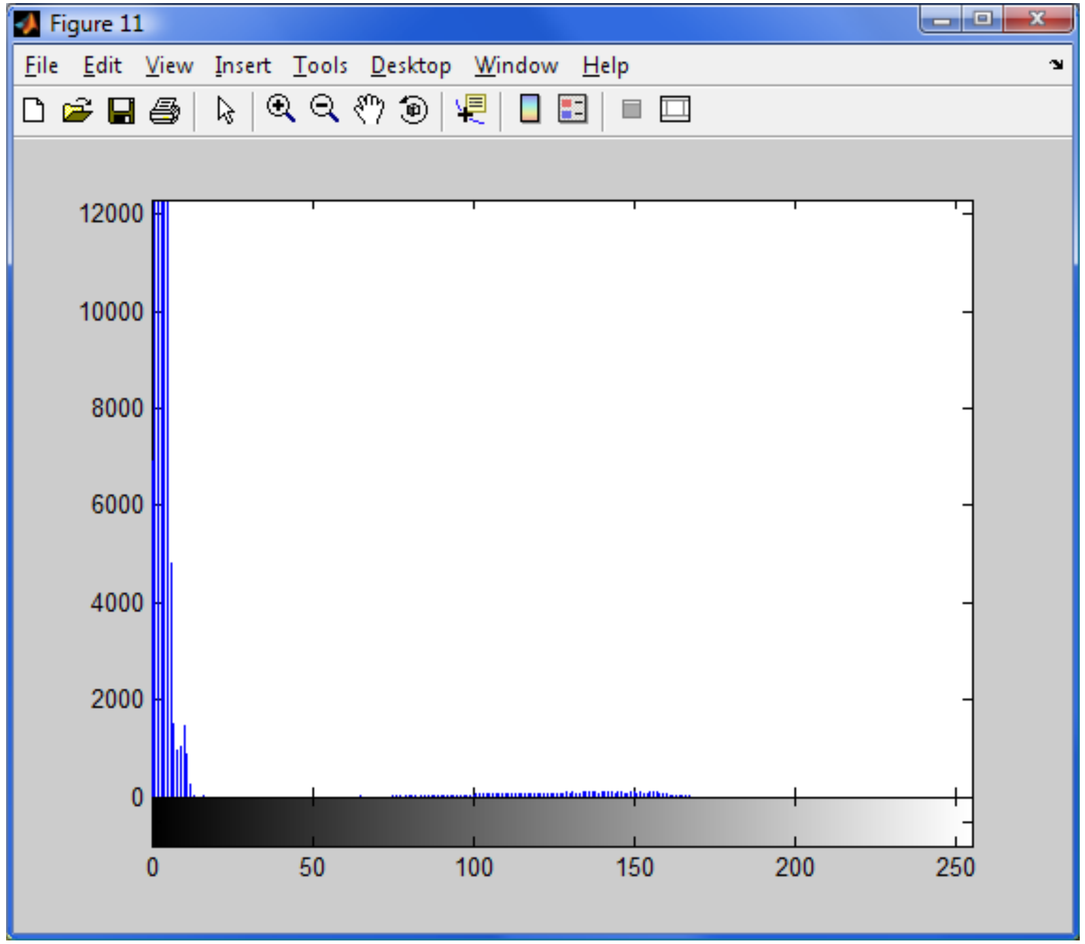


Exclude Dark Pixels?

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

Histogram



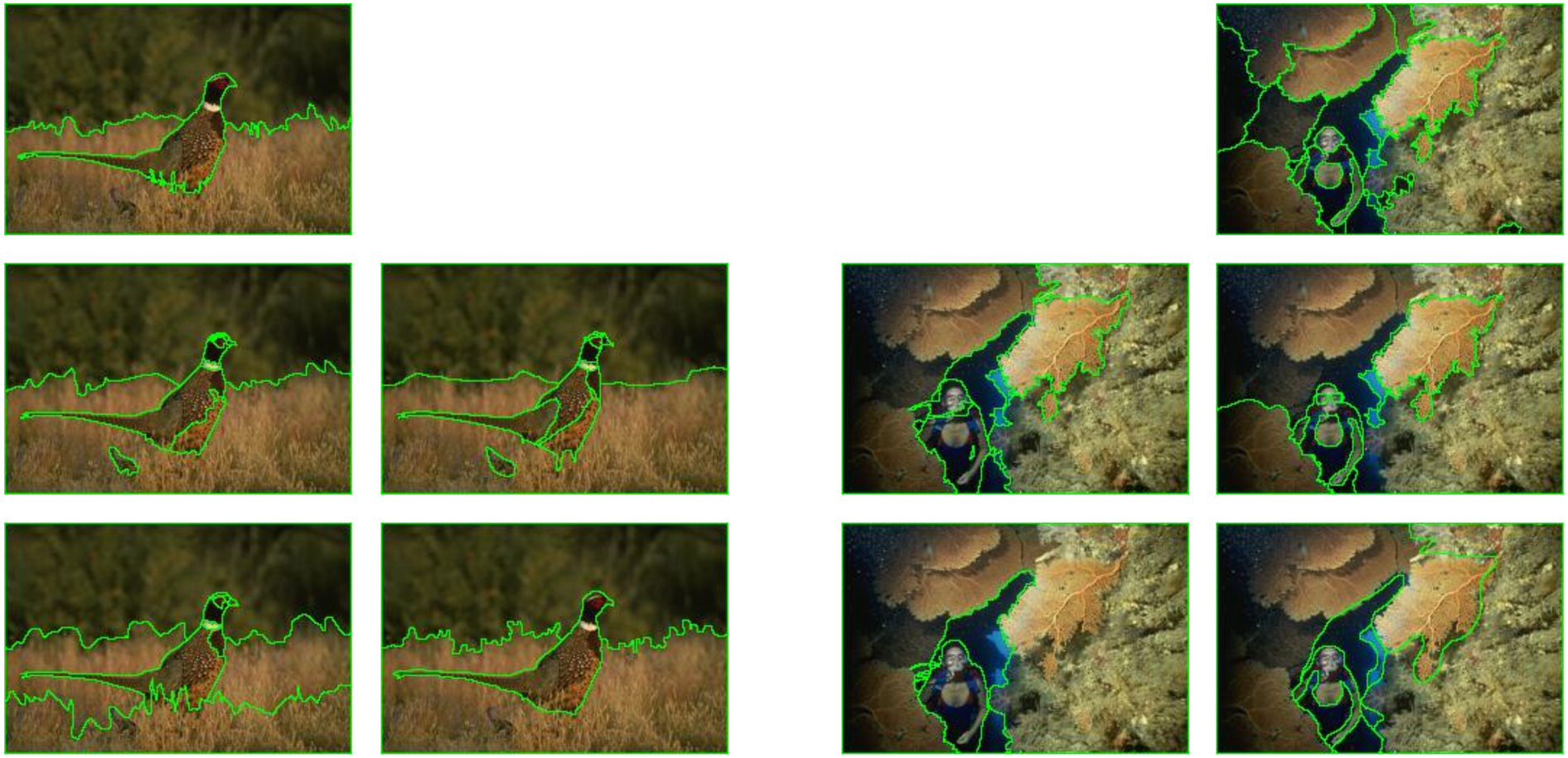
pixels

gray-levels [0,255]

Harder Example

Harder Example

Berkeley Segmentation Database and Benchmark



http://www.eecs.berkeley.edu/Research/Projects/CS/vision/grouping/segbench/

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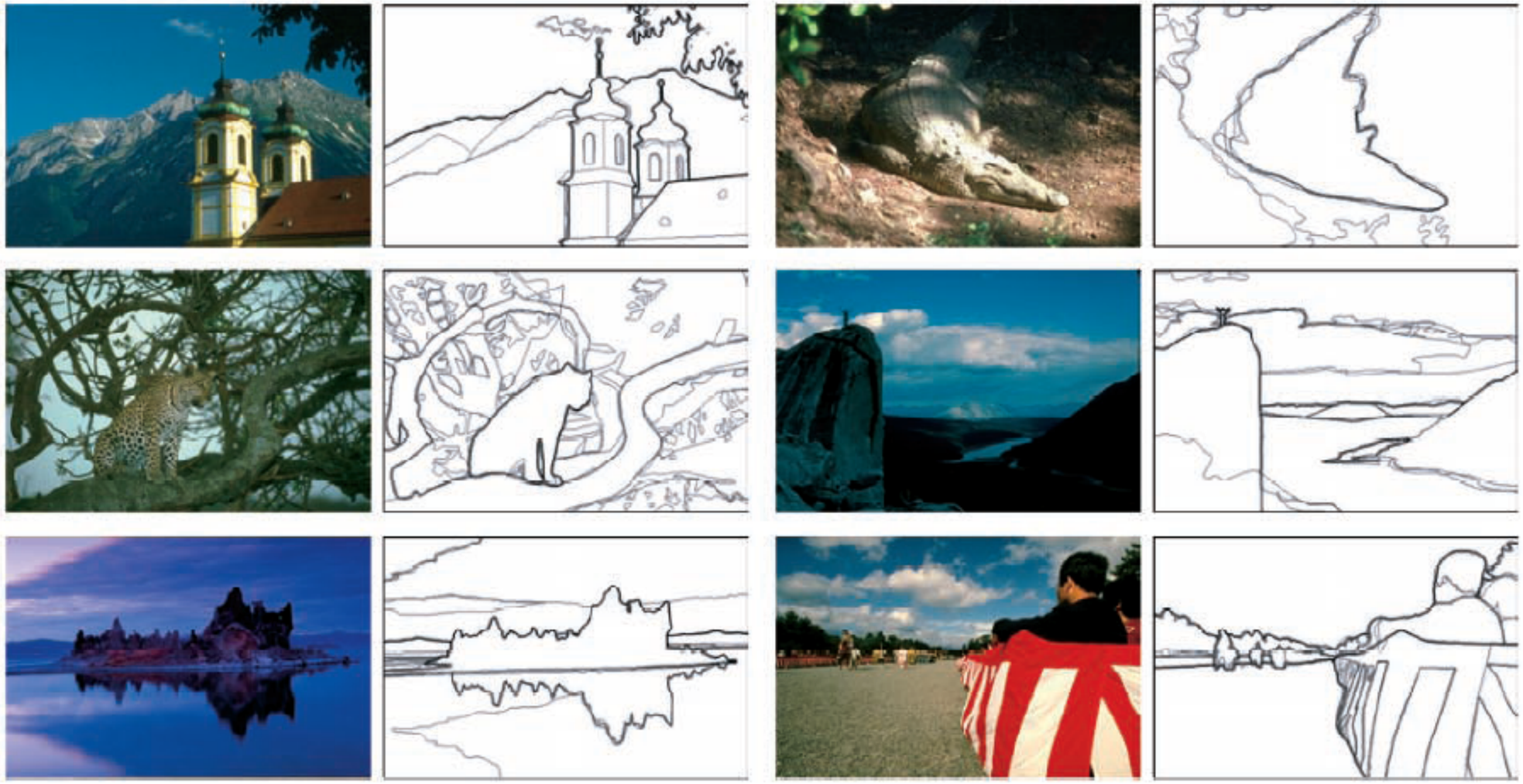
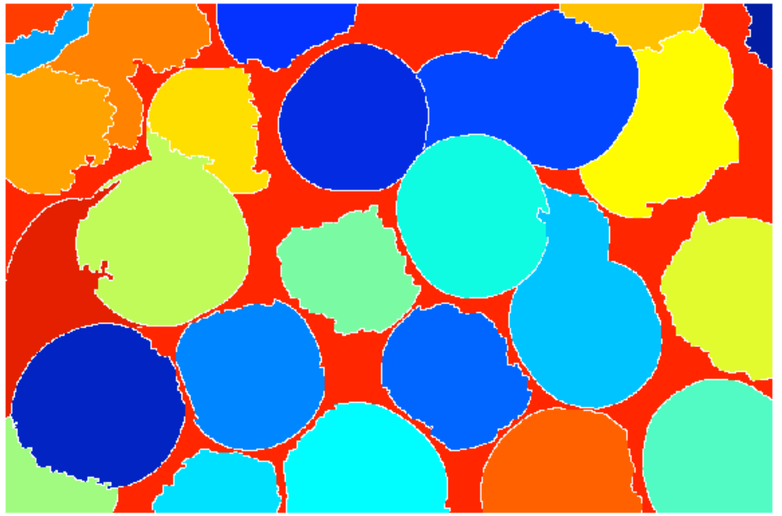


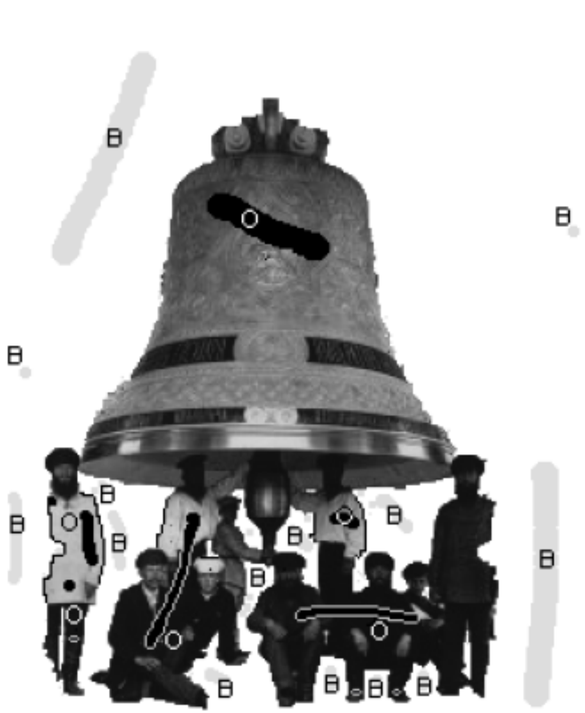
Martin et al. PAMI 2004

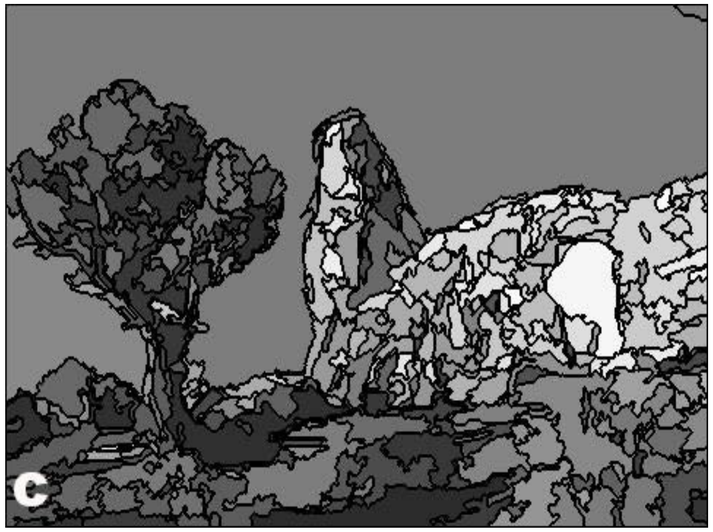
Segmentation Philosophies

Binary vs. Multi-label

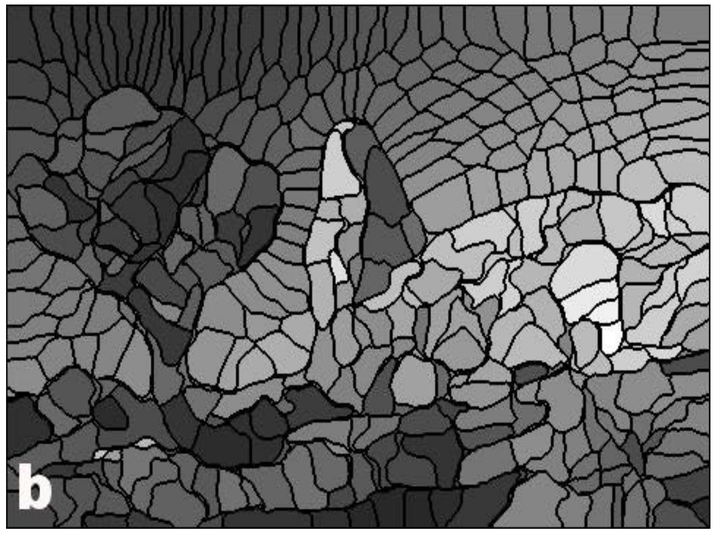


Supervised vs. Unsupervised

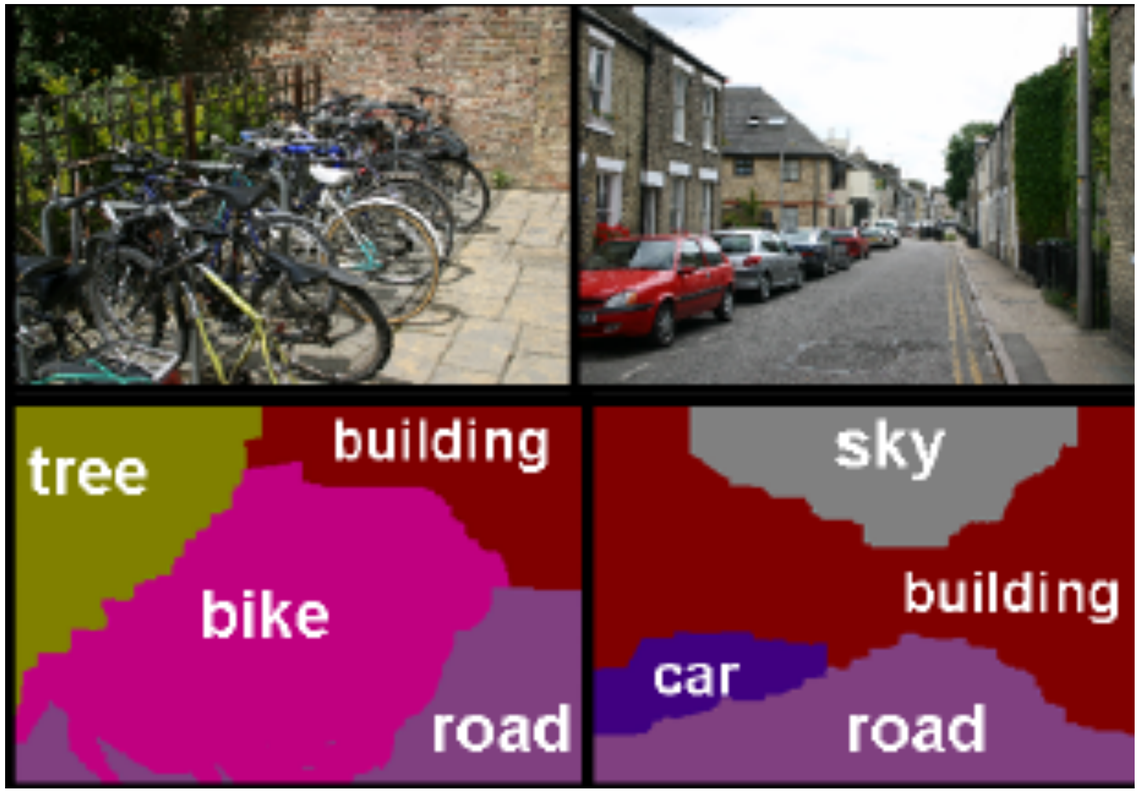




Exact- vs. Over-segmentation



Top-down or Bottom-up



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

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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***:

Intensity

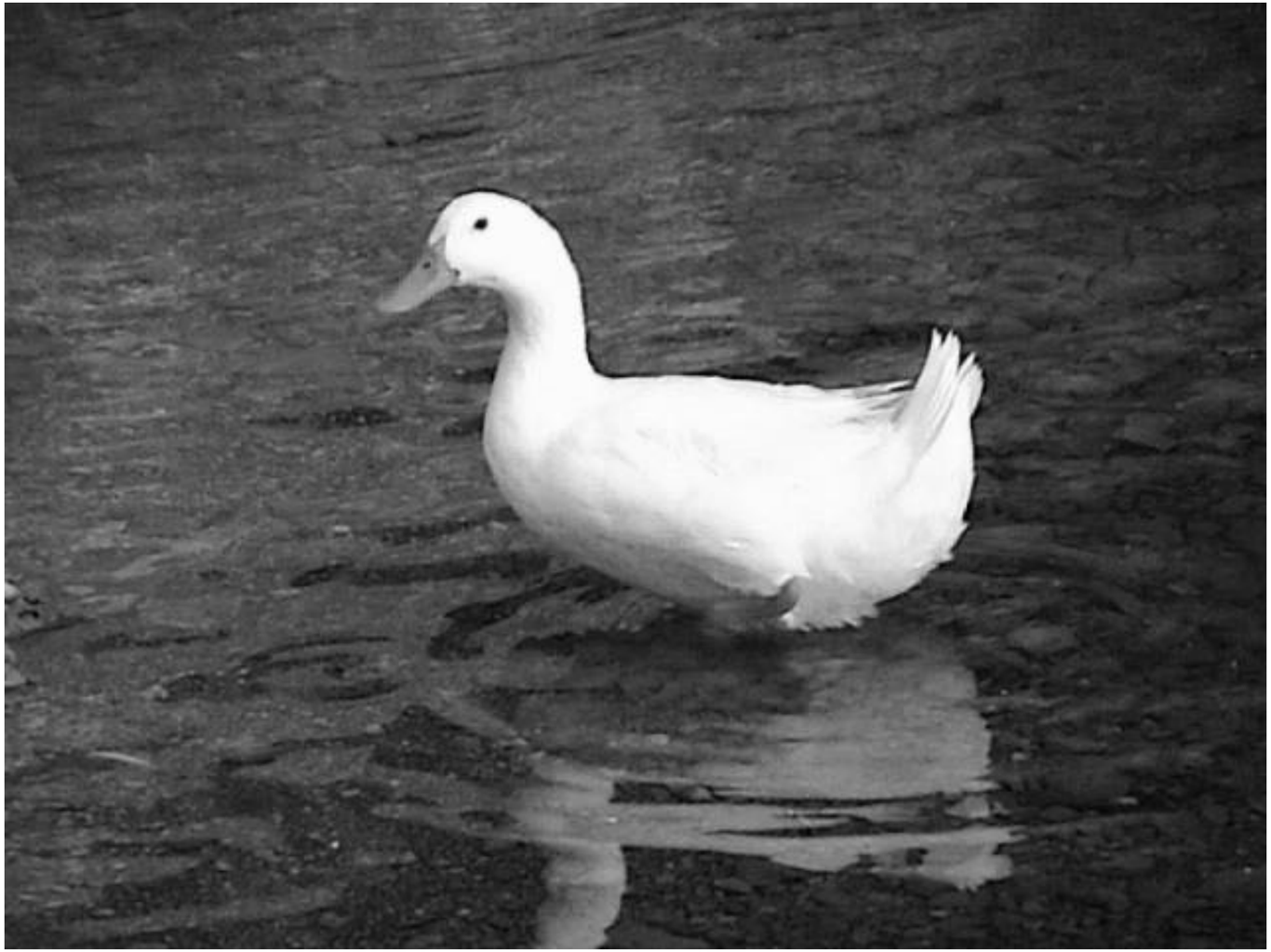
$$B(x,y) = 1 \qquad \text{if } I(x,y) \geq T$$

$$0 \qquad \text{if } I(x,y) < T.$$

Basic Thresholding Algorithm

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

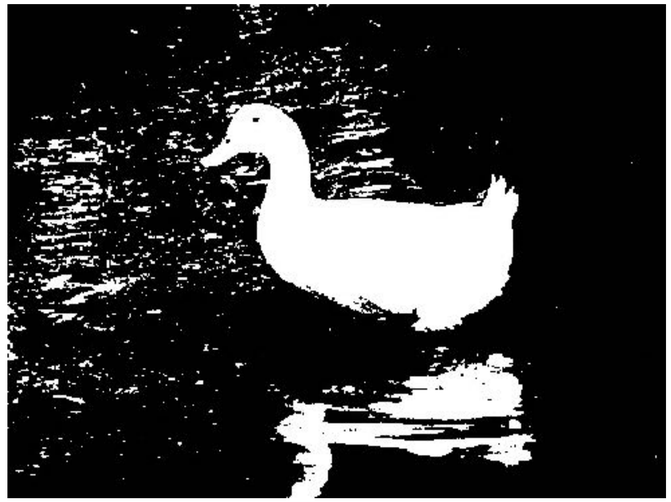
Example



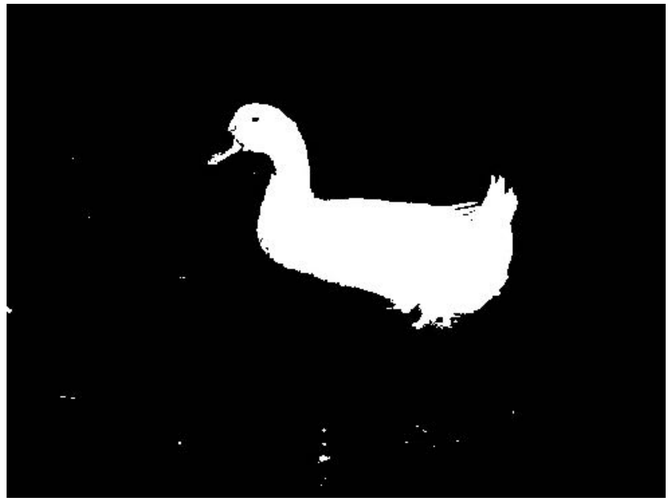
Different Choices for T

T=50

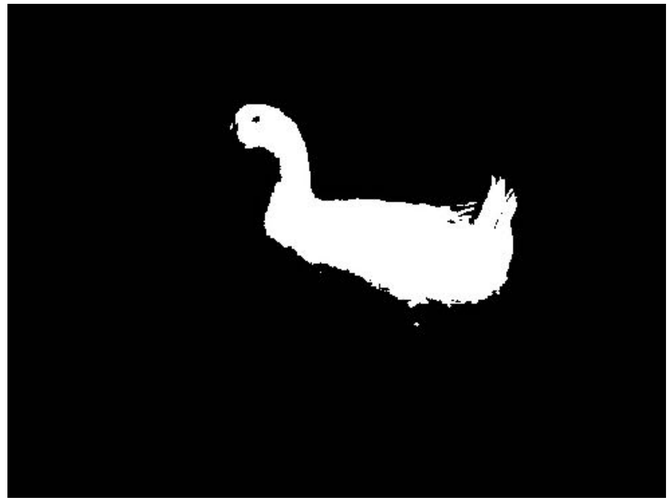
T=100

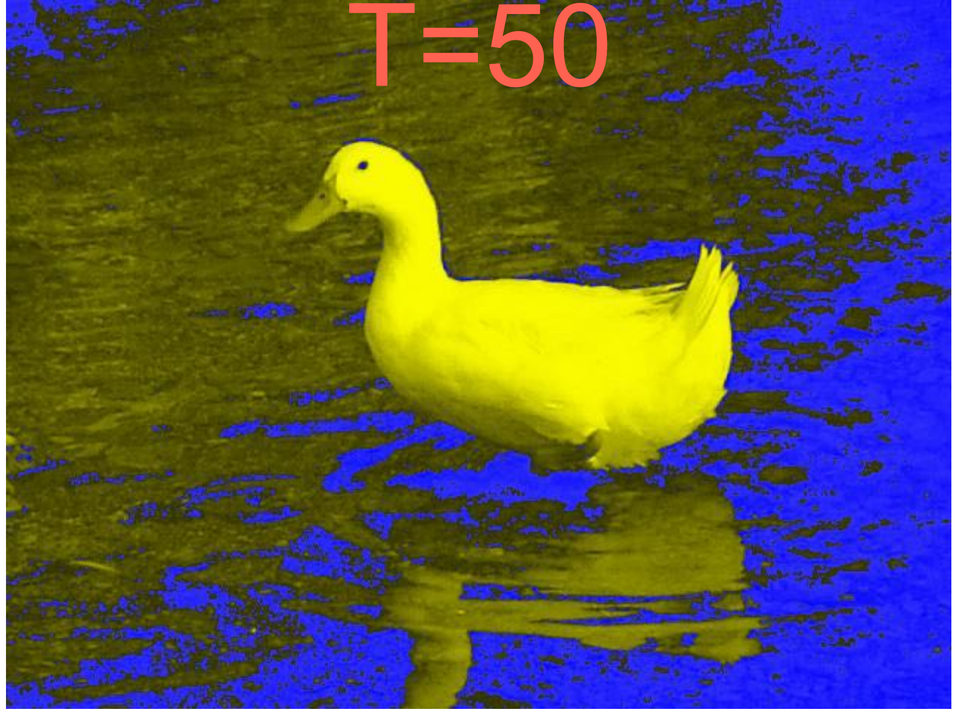


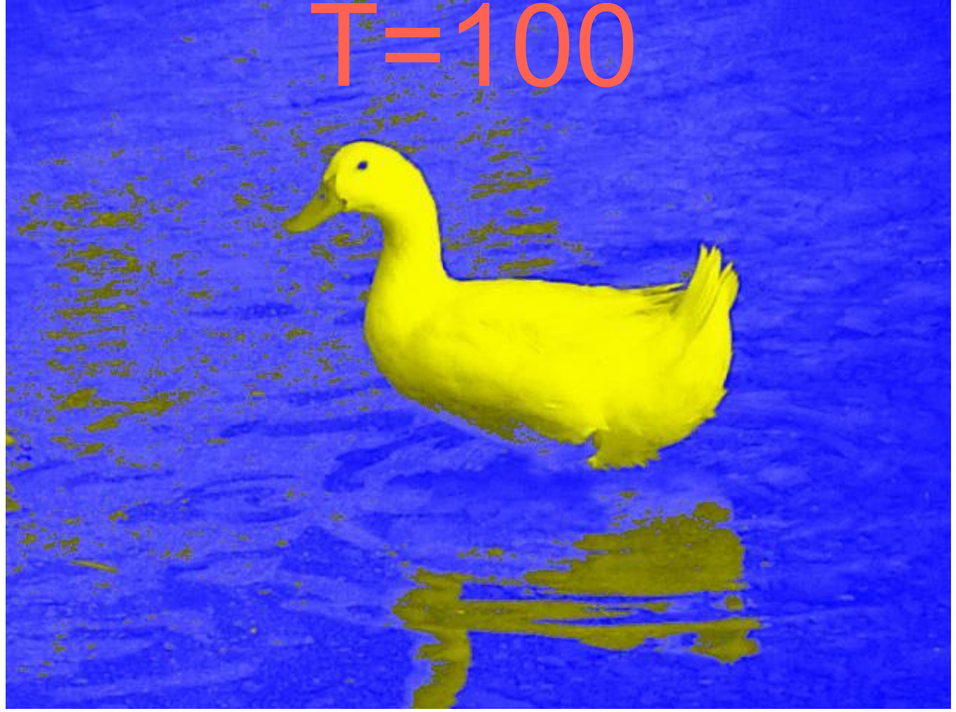
T=150

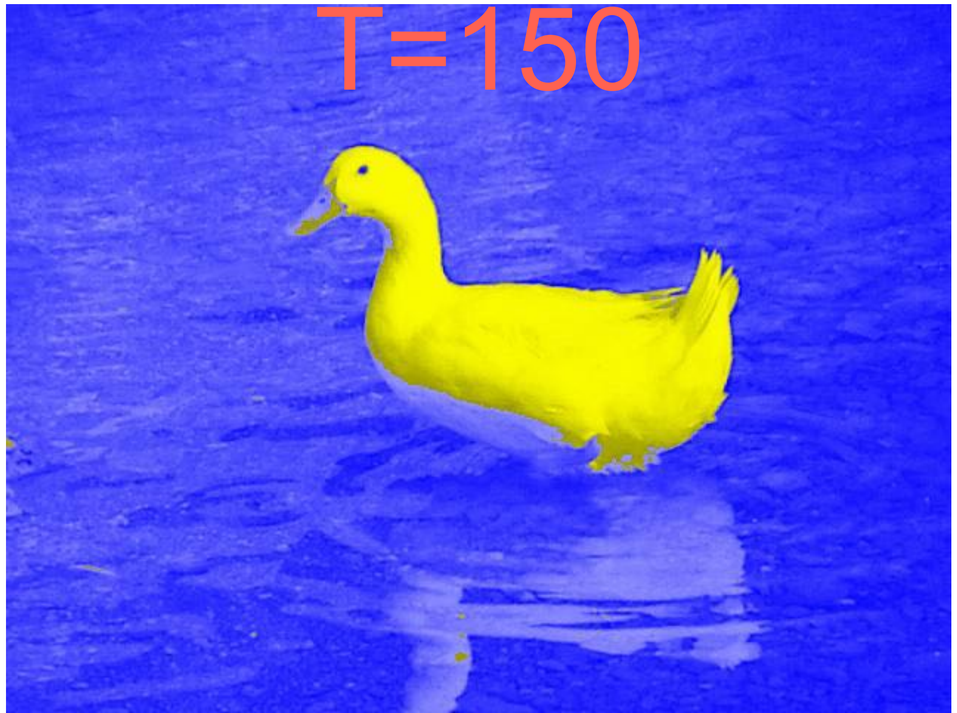


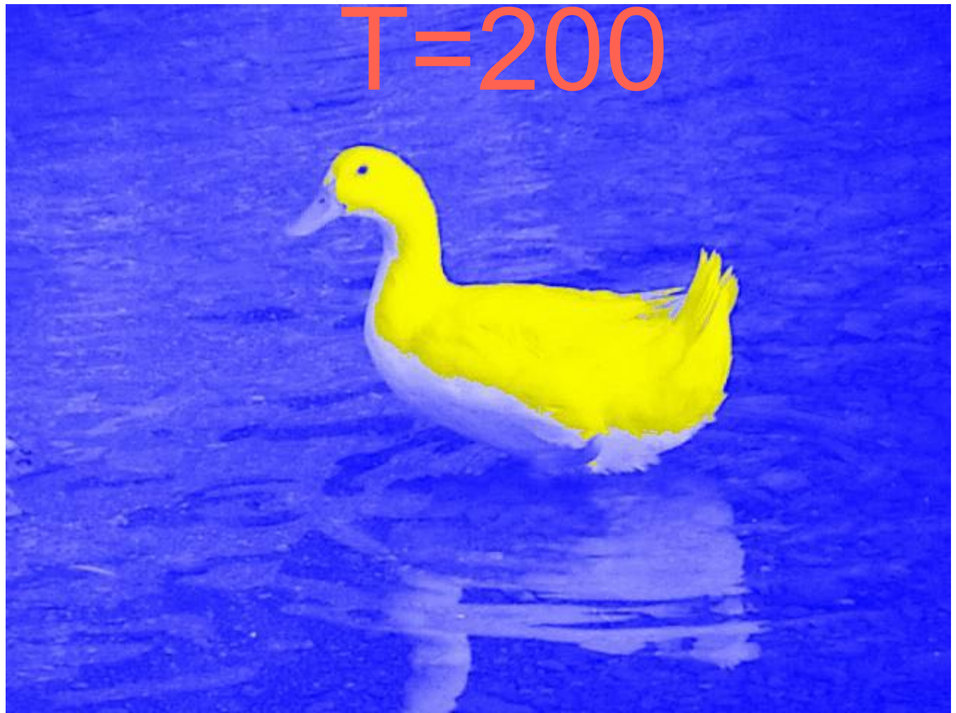
T=200




T=50


T=100

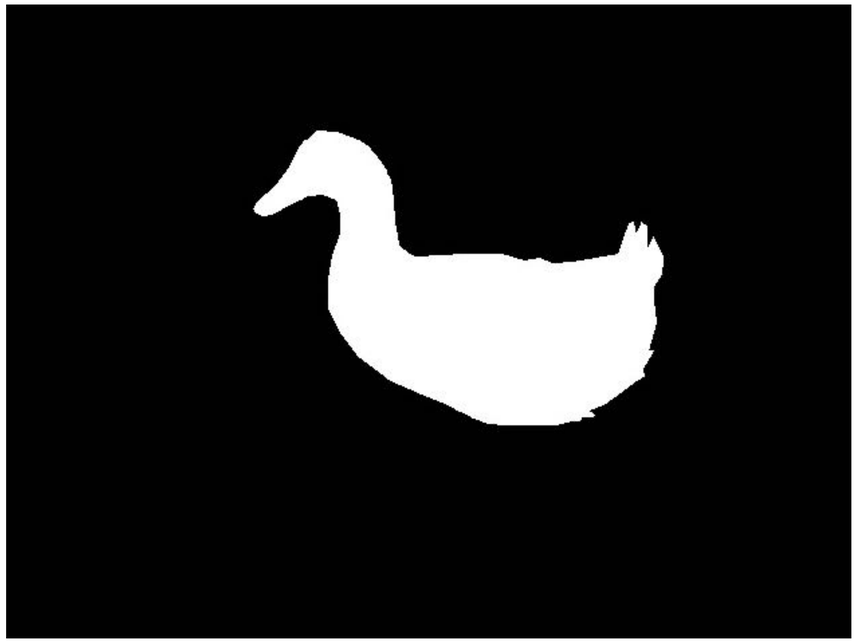

T=150


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 (Receiver operating characteristic) Analysis

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

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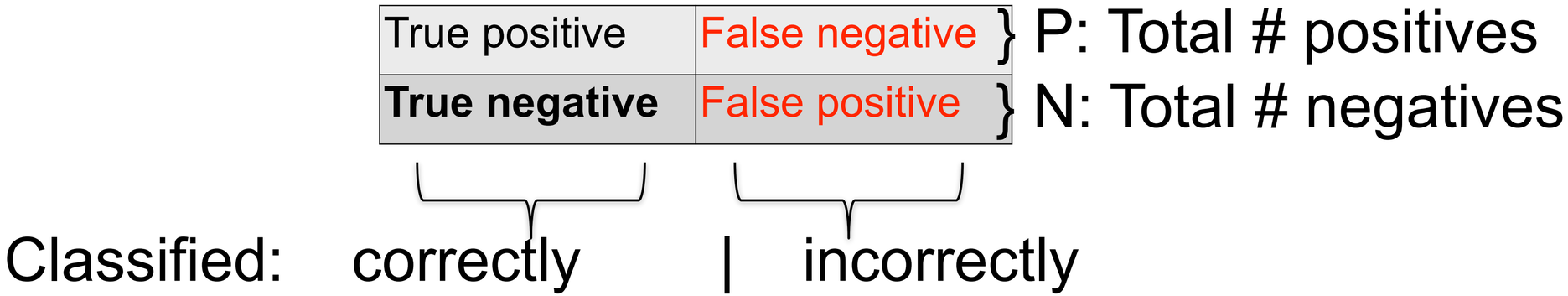
- A binary classifier distinguishes between two different types of thing, e.g.,
  - Healthy/afflicted patients – cancer screening
  - Pregnancy tests
  - Foreground/background image pixels
  - Object detection

Classification Error

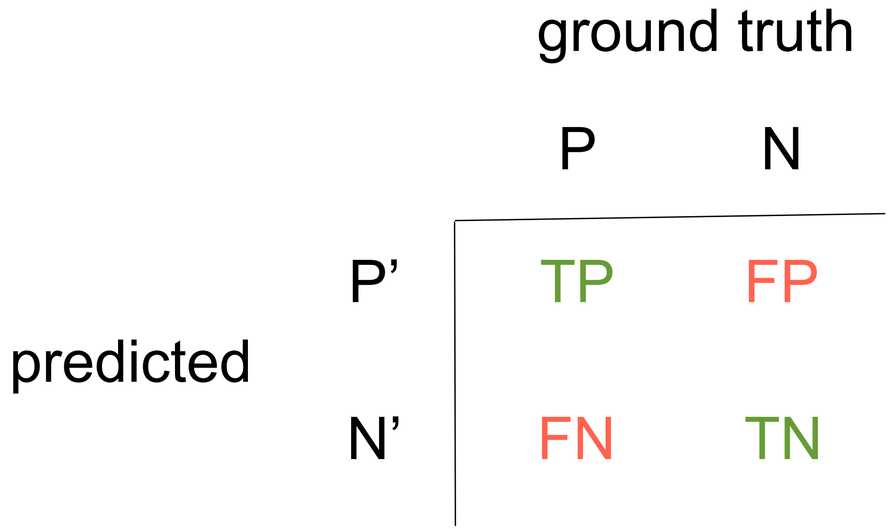
- **Binary classifiers make errors.**
- **Two types of input to a binary classifier:**
  - **Positives**
  - **Negatives**
- **Four possible outcomes in any test:**



ROC Explained

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

ROC Explained



$$\mathrm{TPR} = \mathrm{TP}/\mathrm{P} = \mathrm{TP}/(\mathrm{TP}+\mathrm{FN})$$

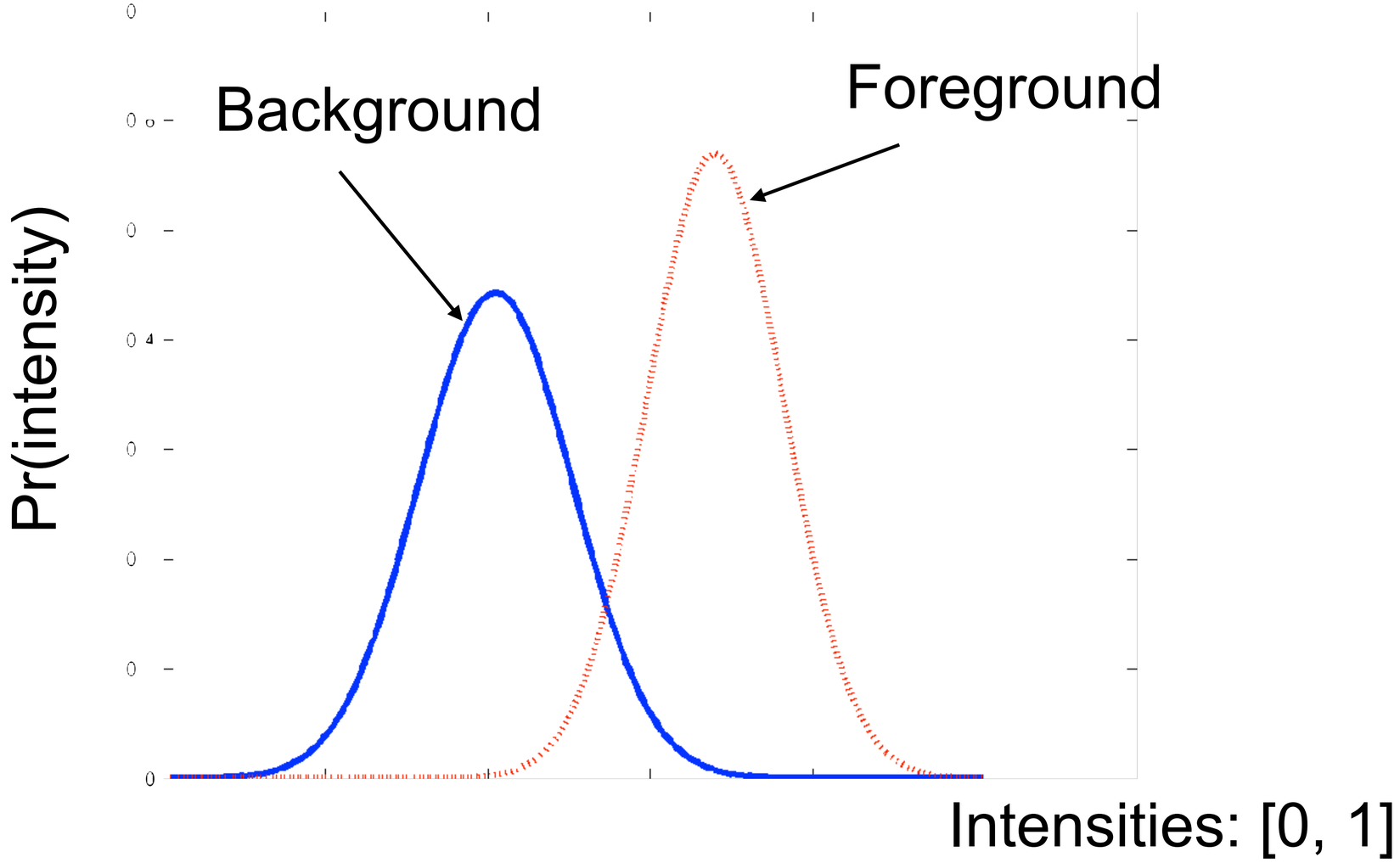
ROC Explained

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

$$\mathrm{TPR} = \mathrm{TP}/\mathrm{P} = \mathrm{TP}/(\mathrm{TP}+\mathrm{FN})$$

$$\mathrm{FPR} = \mathrm{FP}/\mathrm{N} = \mathrm{FP}/(\mathrm{FP}+\mathrm{TN})$$

Real Measurement Distributions



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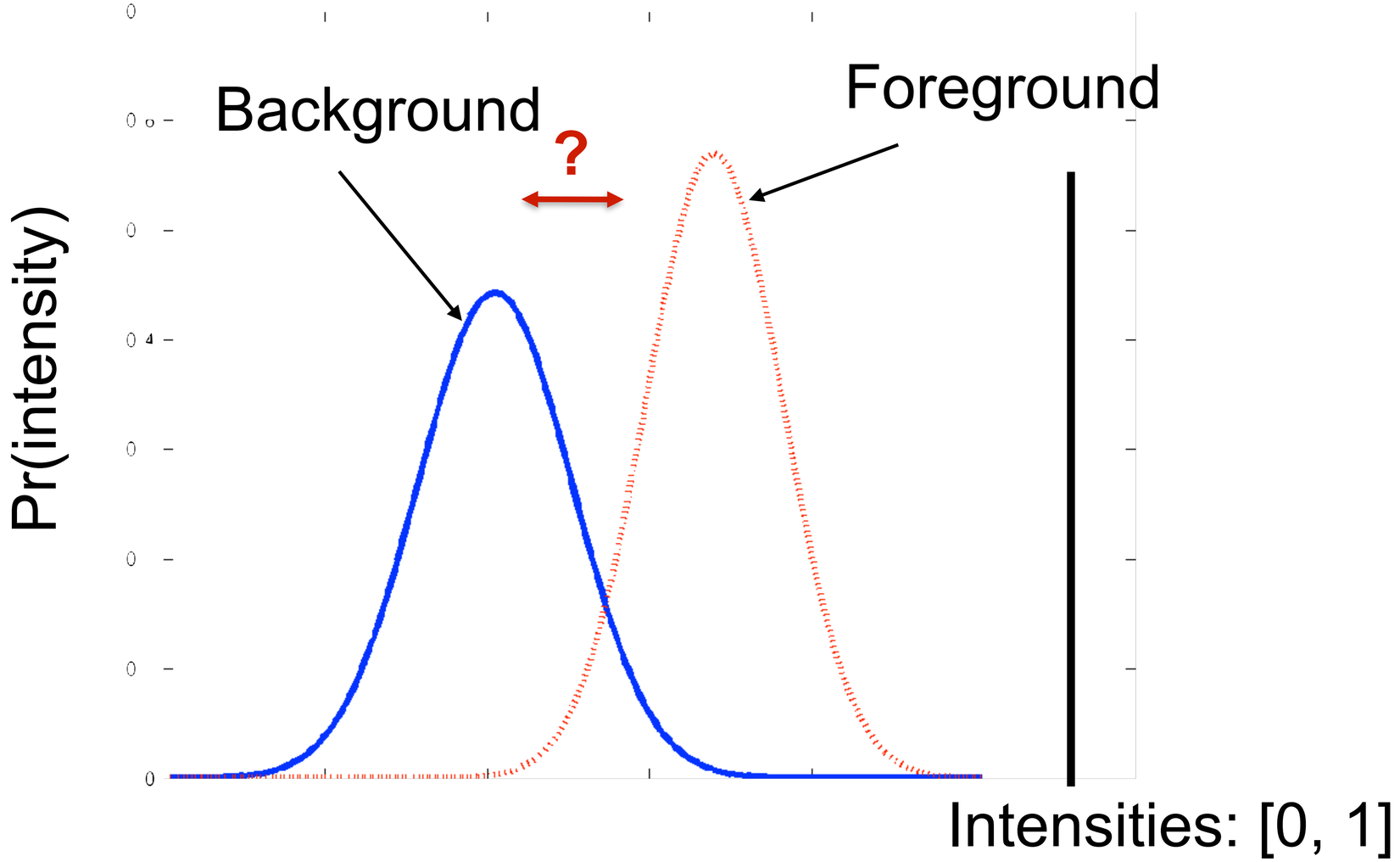

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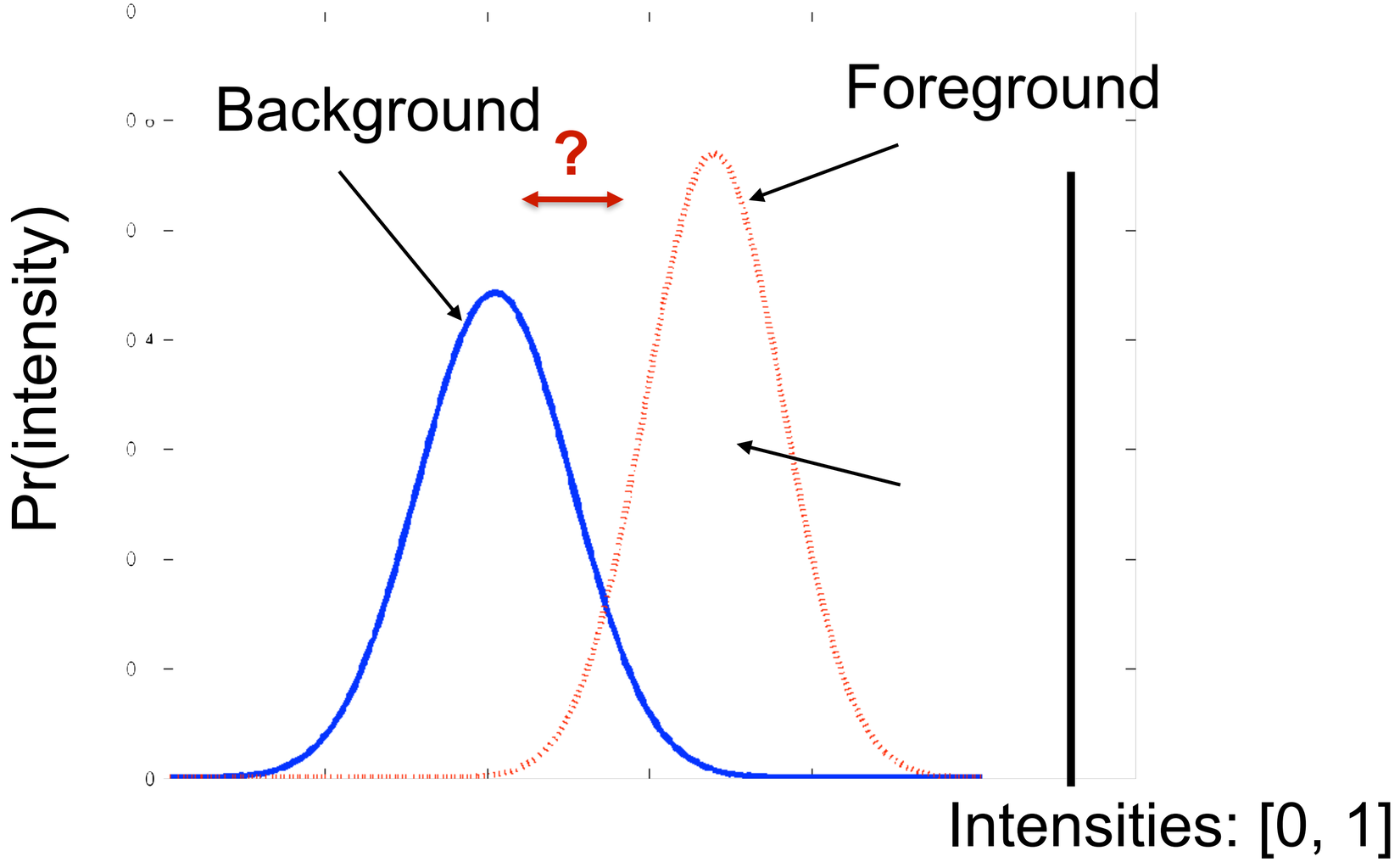
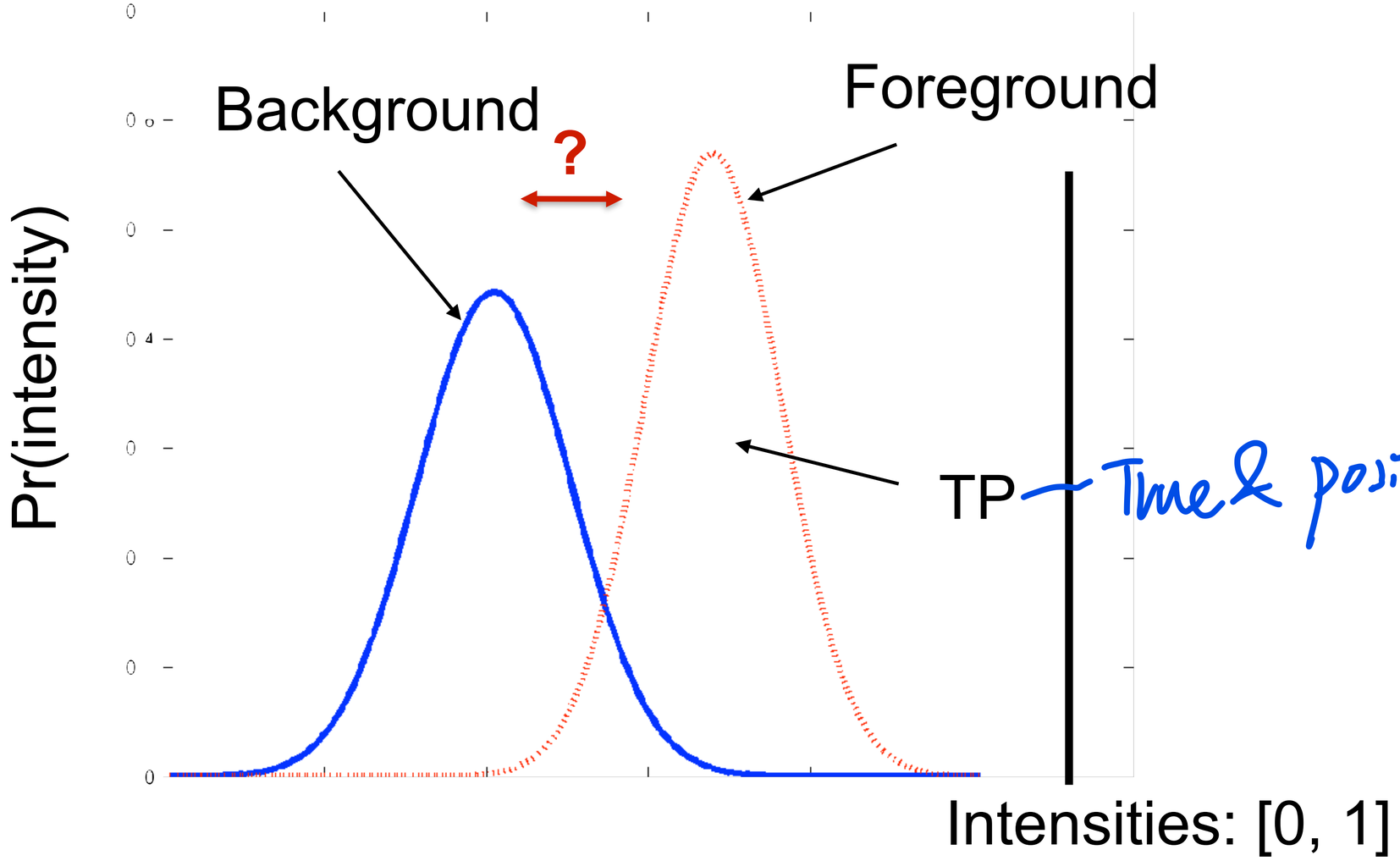
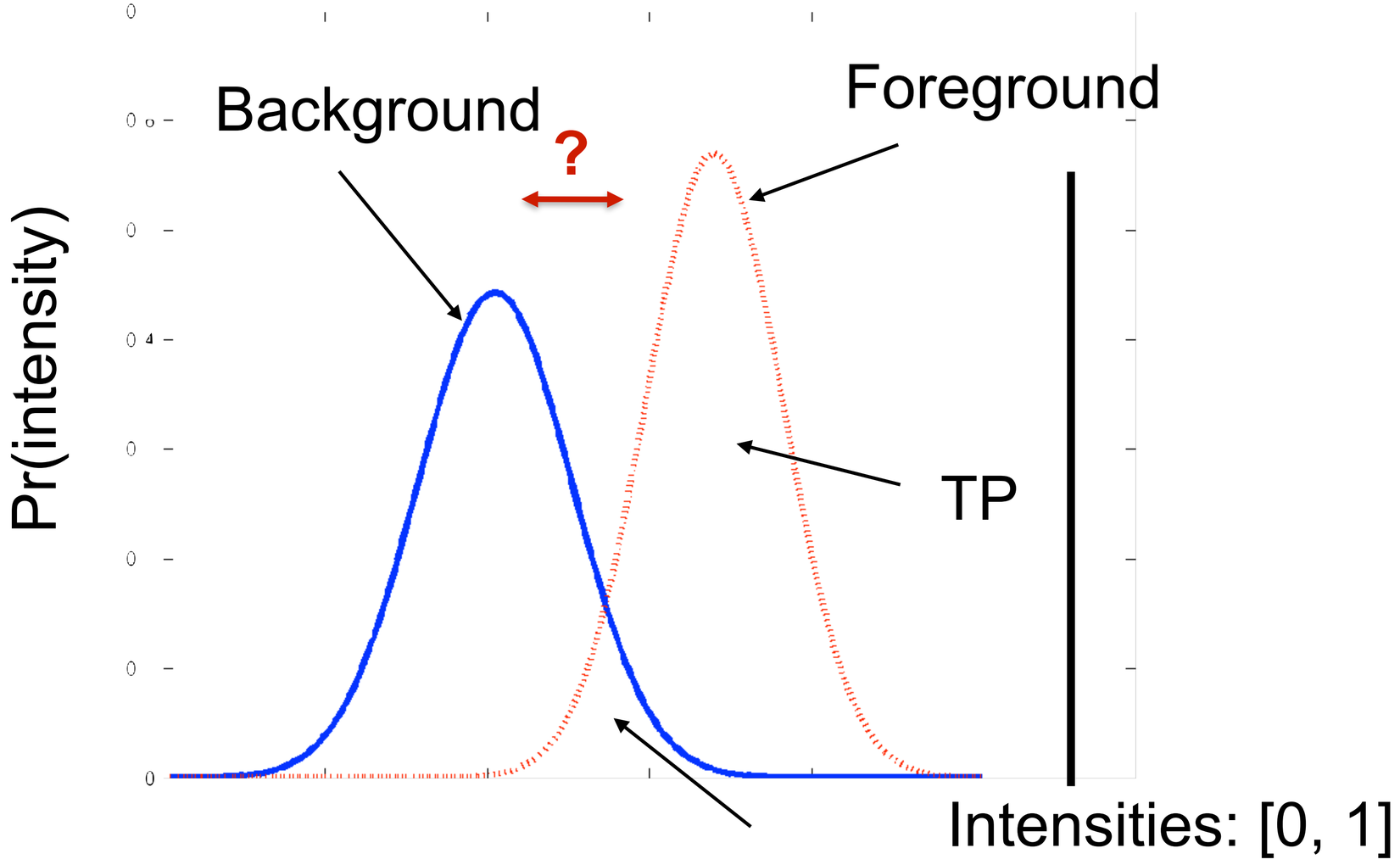


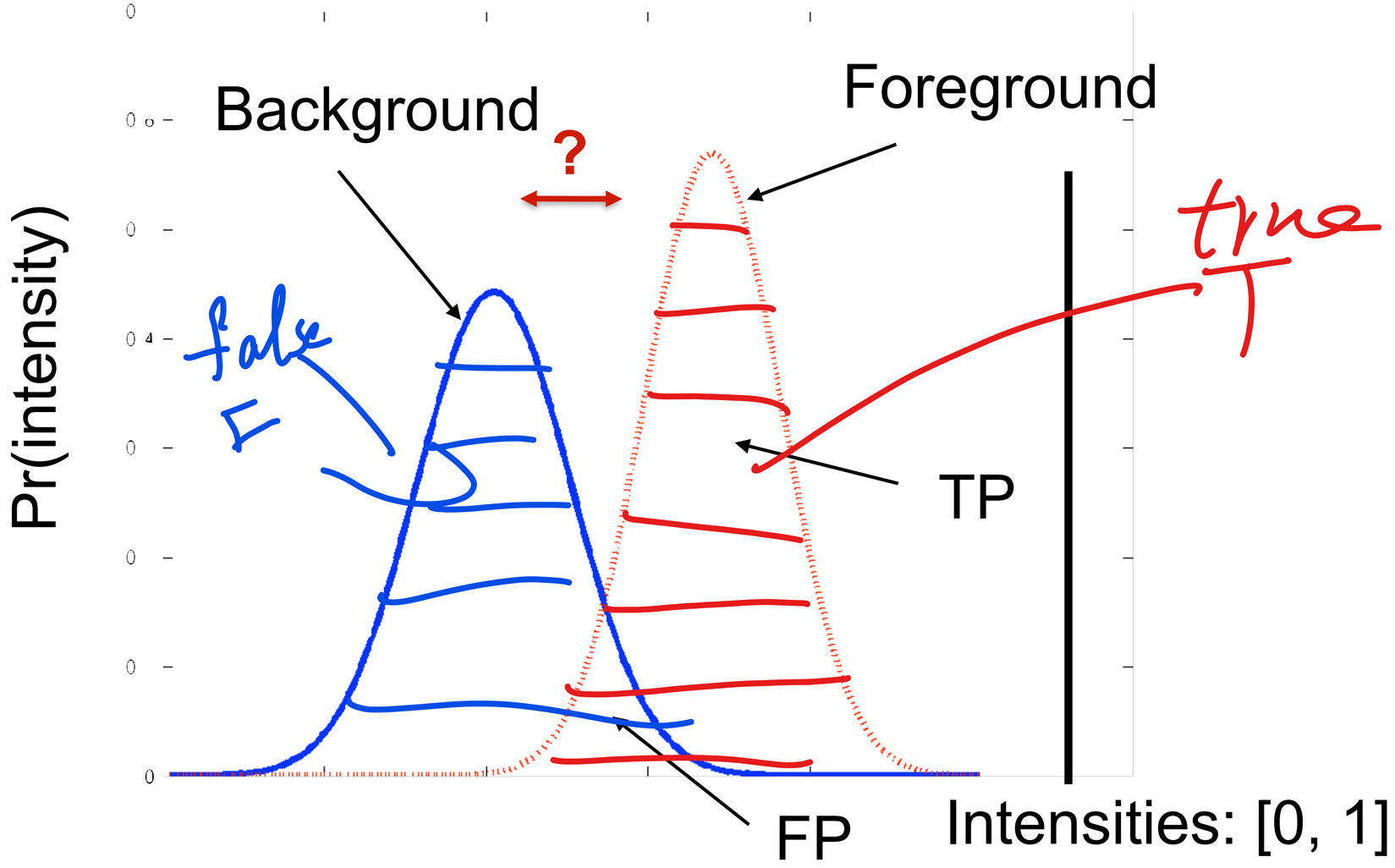
Real Measurement Distributions (辨别 foreground)



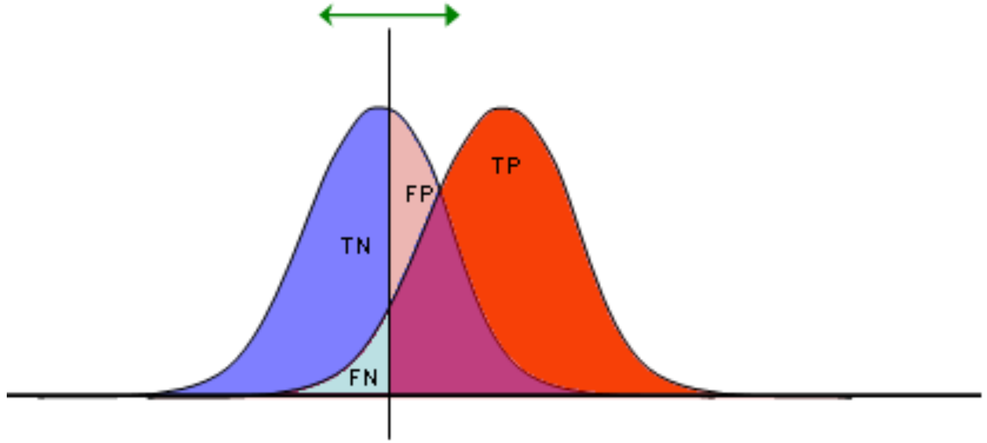
Real Measurement Distributions



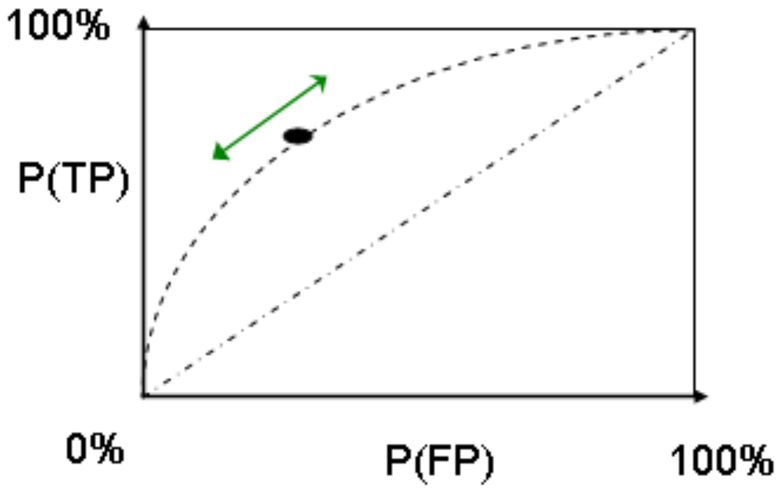
Real Measurement Distributions



ROC Curve

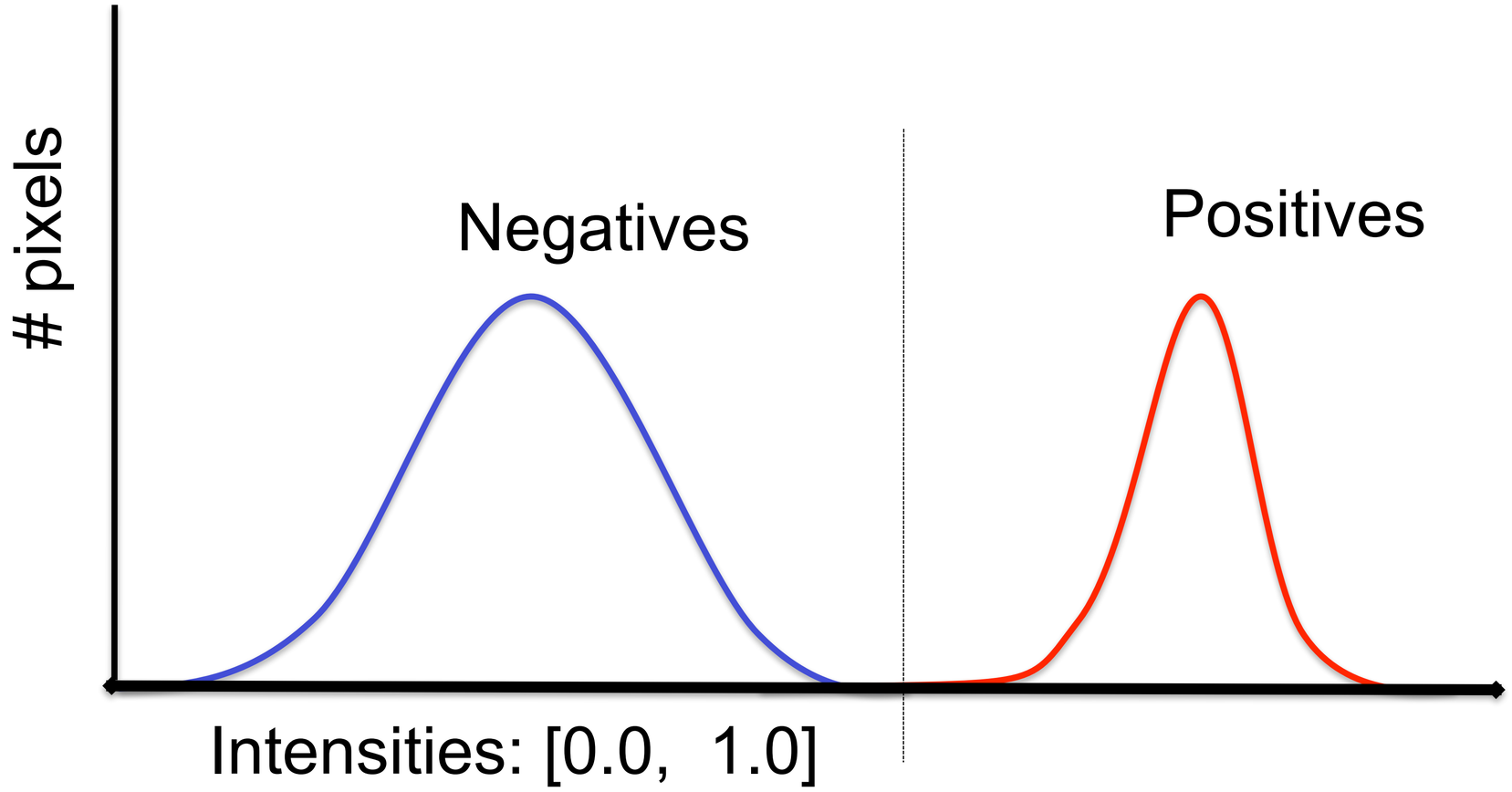


TP	FP
FN	TN
1	1



[wikipedia]

Wouldn’t it be nice…



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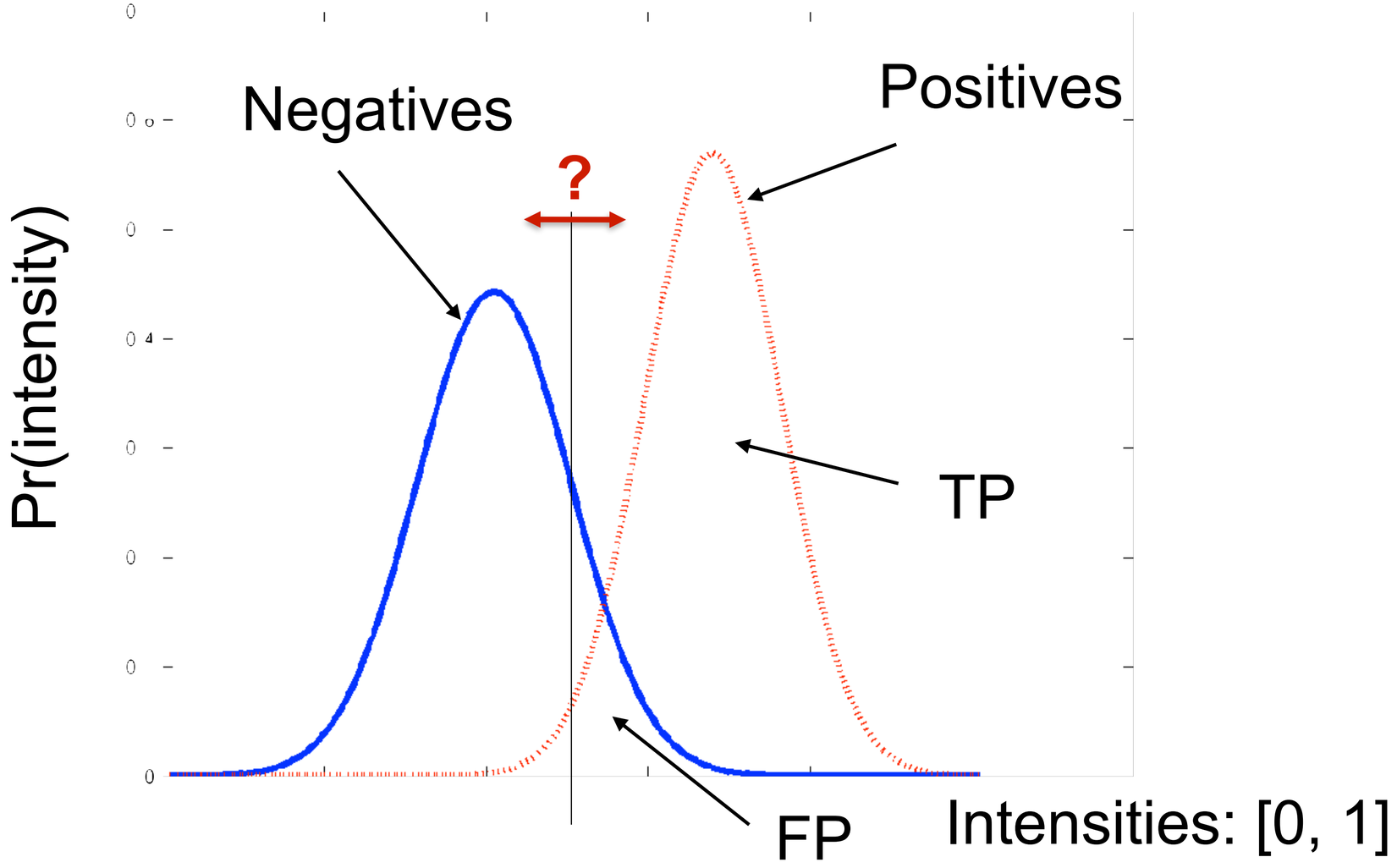

Classification Outcomes

- 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?

positive 和当于和结果对比
negative
false 是GT ground truth
true

The ROC Curve

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- **Characterizes the error trade-off in binary classification tasks.**

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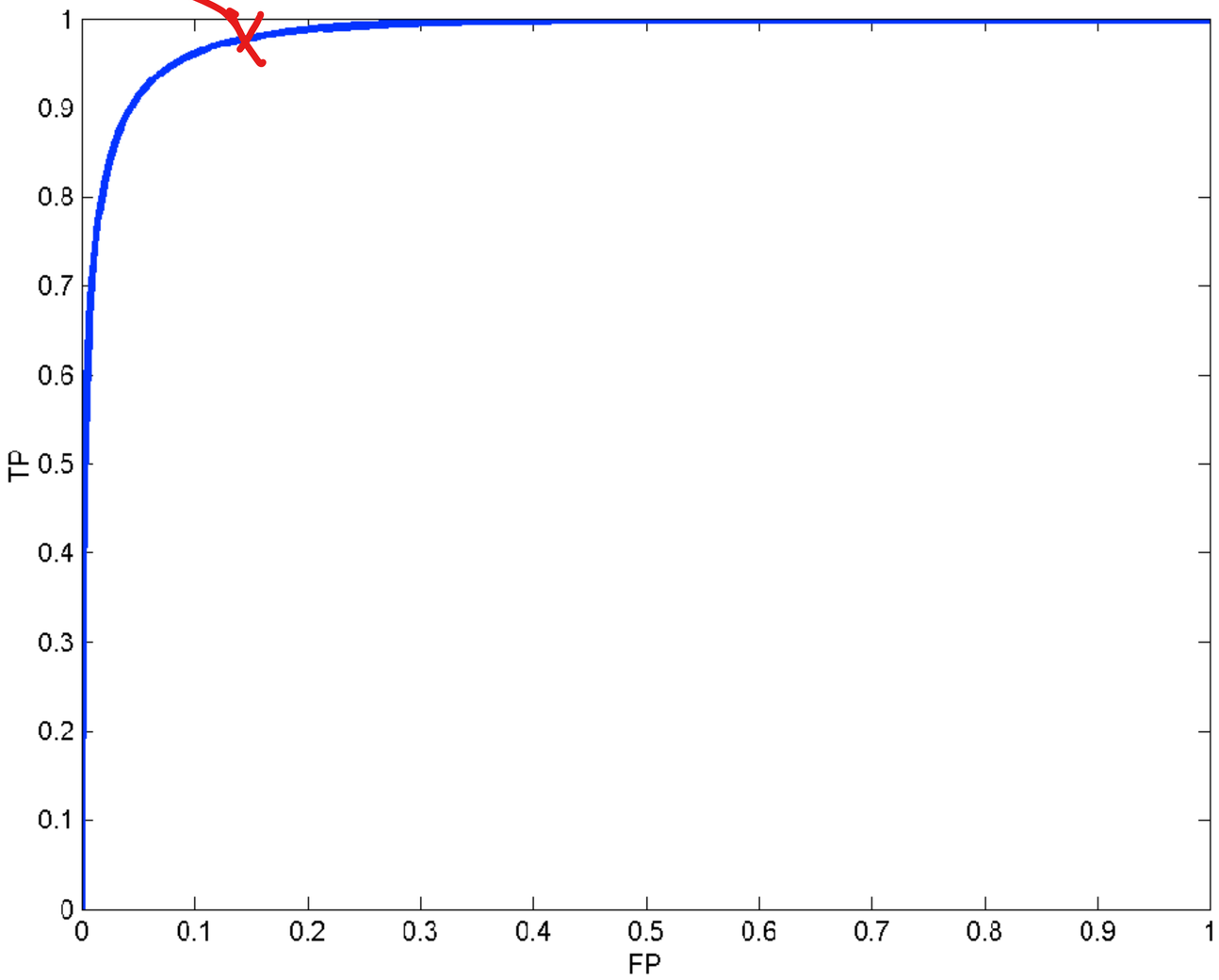
- **Characterizes the error trade-off in binary classification tasks.**
- **It plots the TP fraction against FP fraction.**

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

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

each point
threshold

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



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

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)?

Area under the ROC curve

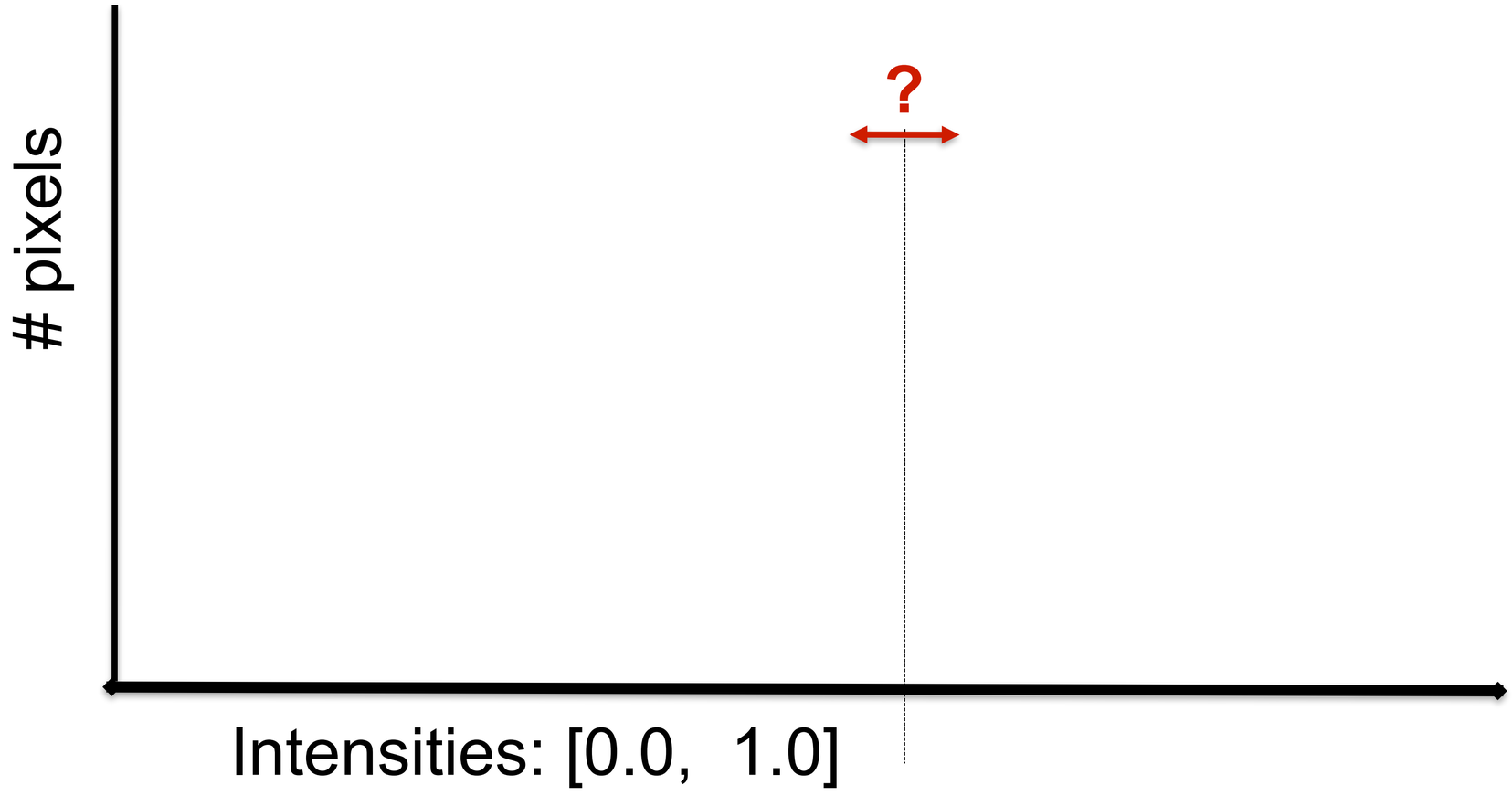
- **The area A under the curve measures overall classification performance.**
- **If the distributions of measurements on positive and negative cases can be modeled as Normal distributions (Gaussians) N with $N(\mu_P, \sigma_P)$ and $N(\mu_N, \sigma_N)$, respectively, then**

$$A = Z\left(\frac{|\mu_P - \mu_N|}{\left(\sigma_P^2 + \sigma_N^2\right)^{1/2}}\right)$$

- **Z is the cumulative normal distribution function**

$$Z(x) = \int_{-\infty}^{x} z(t)dt$$

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