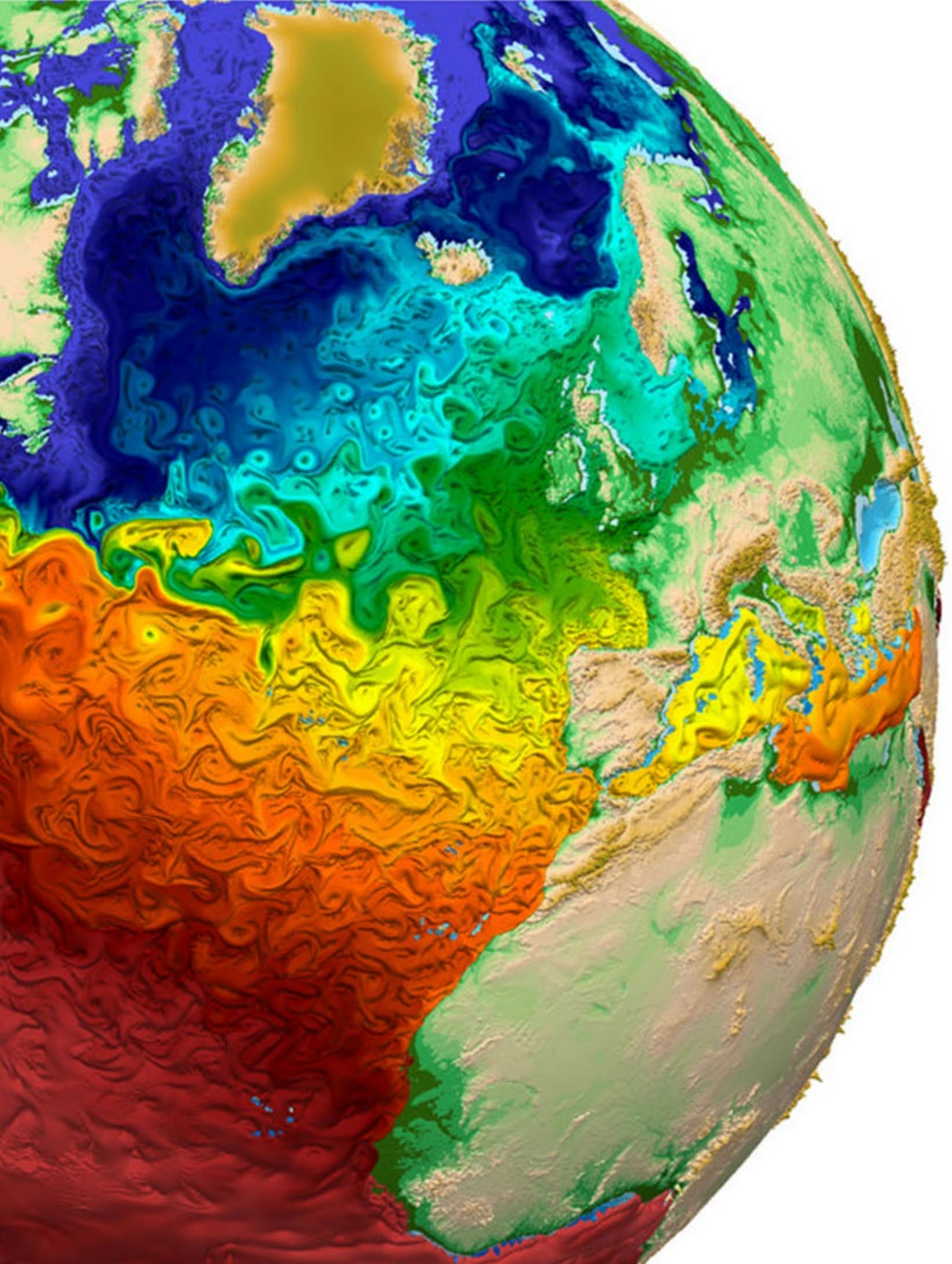

Image Segmentation

Thresholding

Scientific Visualization

Professor Eric Shaffer

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Segmentation by Thresholding

The simplest thresholding methods replace each pixel in an image with a black pixel if the pixel intensity is less than some fixed constant or a white pixel if the image intensity is greater than that constant.
- Wikipedia

Intensity of an (r,g,b) can be computed as (r+g+b)/3.0

Original image

Example of a threshold effect used on an image

- Results in a binary labeling
  - Good approach for segmenting single object or all objects of given type
  - Supports notion of object(s)/foreground vs. background
  - Will not be effective distinguishing multiple objects

Segmentation by Thresholding

Problematic in real-world conditions

- Images are not taken under perfectly uniform illumination (or radiation, contrast agent, etc.)
- Optical imaging devices are typically not equally sensitive across their field of view

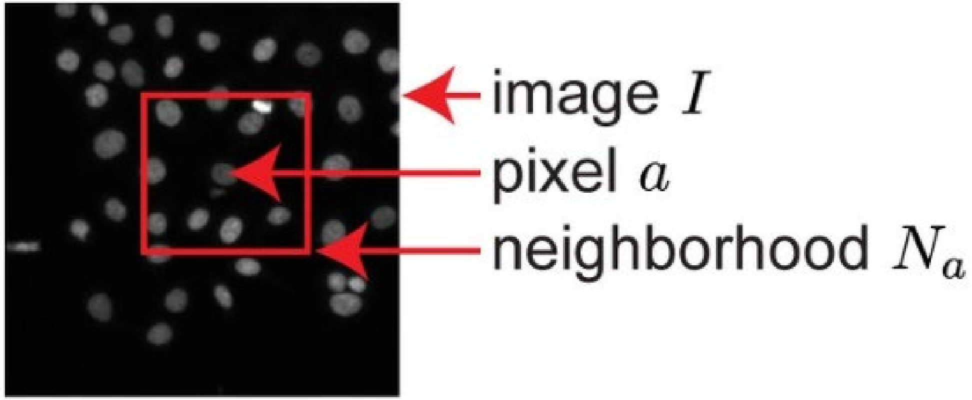
The same object has different intensities at different locations in an image

- Can try to handle this by local thresholding

Local Thresholding

Some options

- Tessellate the image into rectangular blocks
  - Use different threshold parameter(s) for each block
- Use a moving window



Global threshold: $\tau = f(\{i \in I\})$

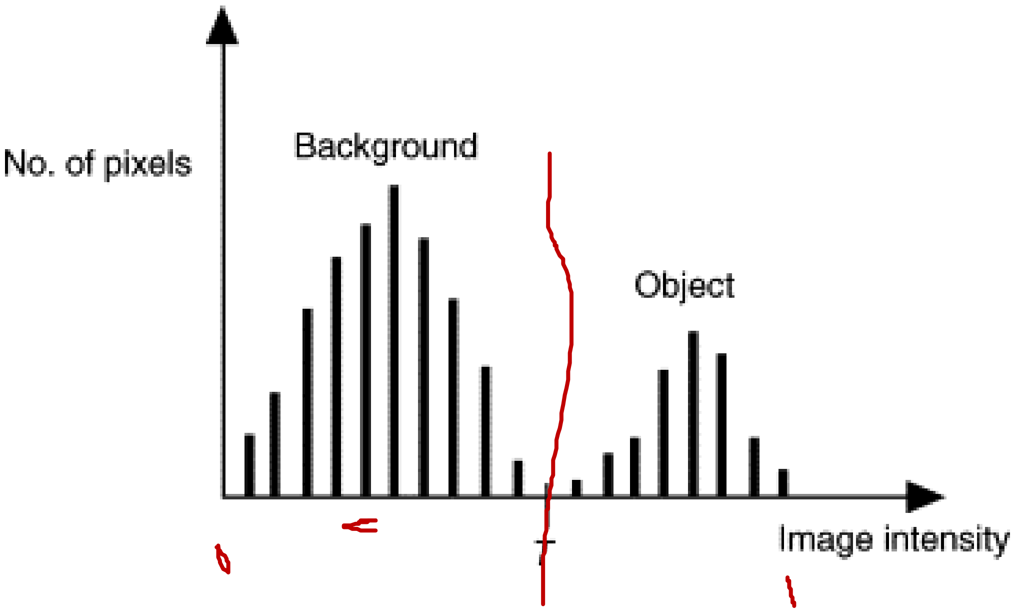
Local threshold: $\tau_a = f(\{i \in N_a\})$

Computing Thresholds

- In very limited cases:
  - Multiple, similar objects imaged under virtually identical conditions
  - Choose a good threshold manually for the first object
  - Use that threshold for all future objects
- Most of the time:
  - Different objects under different conditions
  - Need to automate the selection of thresholds
  - Many ways to do this

Computing Thresholds

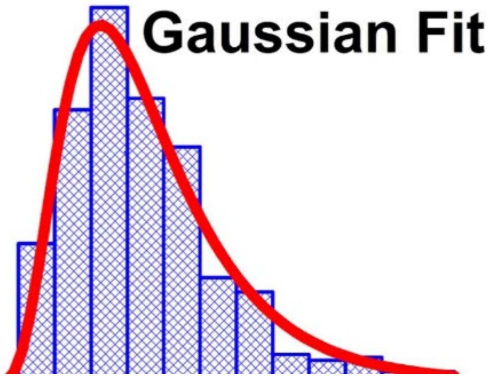
- If we expect lots of contrast, then use:
  - $T = i_{avg} + \varepsilon$
- More typically, use histogram analysis

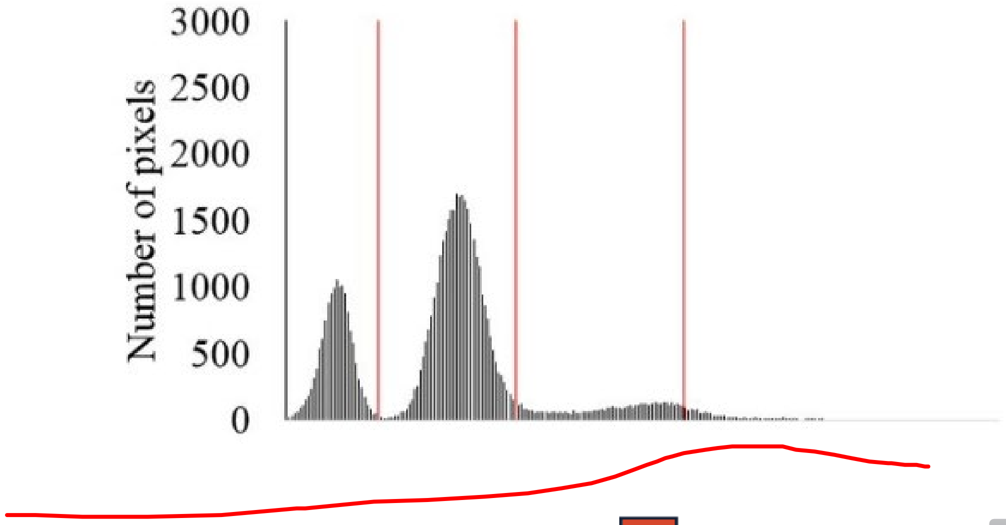


Intensity of an (r,g,b) can be computed as (r+g+b)/3.0

Histogram Analysis

- Idea: Choose a threshold between the peaks
- Histograms often require pre-processing
- How to find the peaks?
  - Try fitting Gaussians to the histogram
  - Use their intersection(s) as the threshold(s)
  - How many Gaussians to try to fit?
    - Requires prior knowledge…or maybe Machine Learning





Otsu’s Method

In the simplest form, the algorithm returns a single intensity threshold that separate pixels into two classes, foreground and background. This threshold is determined by minimizing intra-class intensity variance, or equivalently, by maximizing inter-class variance.
- Wikipedia

An example image thresholded using Otsu's algorithm

The algorithm searches for the threshold that minimizes

$$\sigma^2_w(t) = \omega_0(t)\sigma^2_0(t) + \omega_1(t)\sigma^2_1(t)$$

the intra-class variance, defined as a weighted sum of variances of the two classes

Weights ω_0 and ω_1 are the probabilities of the two classes separated by a threshold t ,and σ^2_0 and σ^2_1 are variances of these two classes.

Original image

And…what is variance again?

For a discrete random variable X

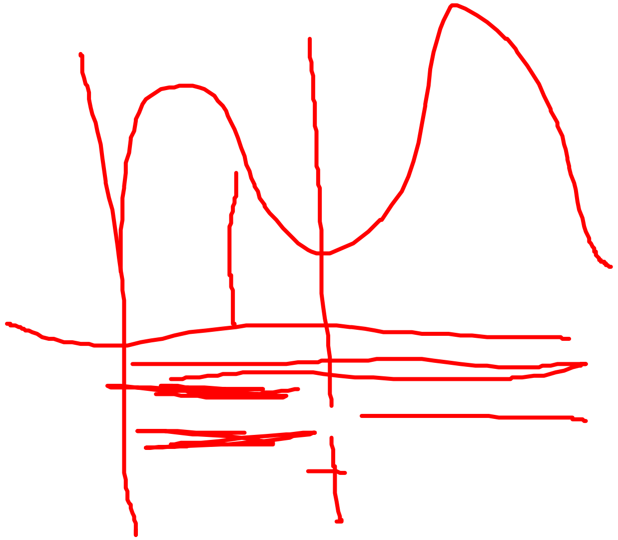
$$\mathrm{Var}(X) = \sum_{i=1}^{n} p_i \cdot (x_i - \mu)^2$$

μ is the average
Pi is the Probability the X →xi

Informally, it measures how far a set of numbers is spread out from their average value.

Computing the Weights

Weights ω_0 and ω_1 are the probabilities of the two classes separated by a threshold t ,and σ_0^2 and σ_1^2 are variances of these two classes.



$$\omega_0(t) = \sum_{i=0}^{t-1} p(i)$$

The class probability is computed from the L bins of the histogram

$$\omega_1(t) = \sum_{i=t}^{L-1} p(i)$$

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Maximizing the Gap

For 2 classes, minimizing the intra-class variance is equivalent to maximizing inter-class variance

..search for best gap…find t maxing:

$$\omega_0(t)\omega_1(t)\left[\mu_0(t) - \mu_1(t)\right]^2$$

$$\omega_0(t) = \sum_{i=0}^{t-1} p(i) \qquad \mu_0(t) = \frac{\sum_{i=0}^{t-1} ip(i)}{\omega_0(t)}$$

$$\omega_1(t) = \sum_{i=t}^{L-1} p(i) \qquad \mu_1(t) = \frac{\sum_{i=t}^{L-1} ip(i)}{\omega_1(t)}$$

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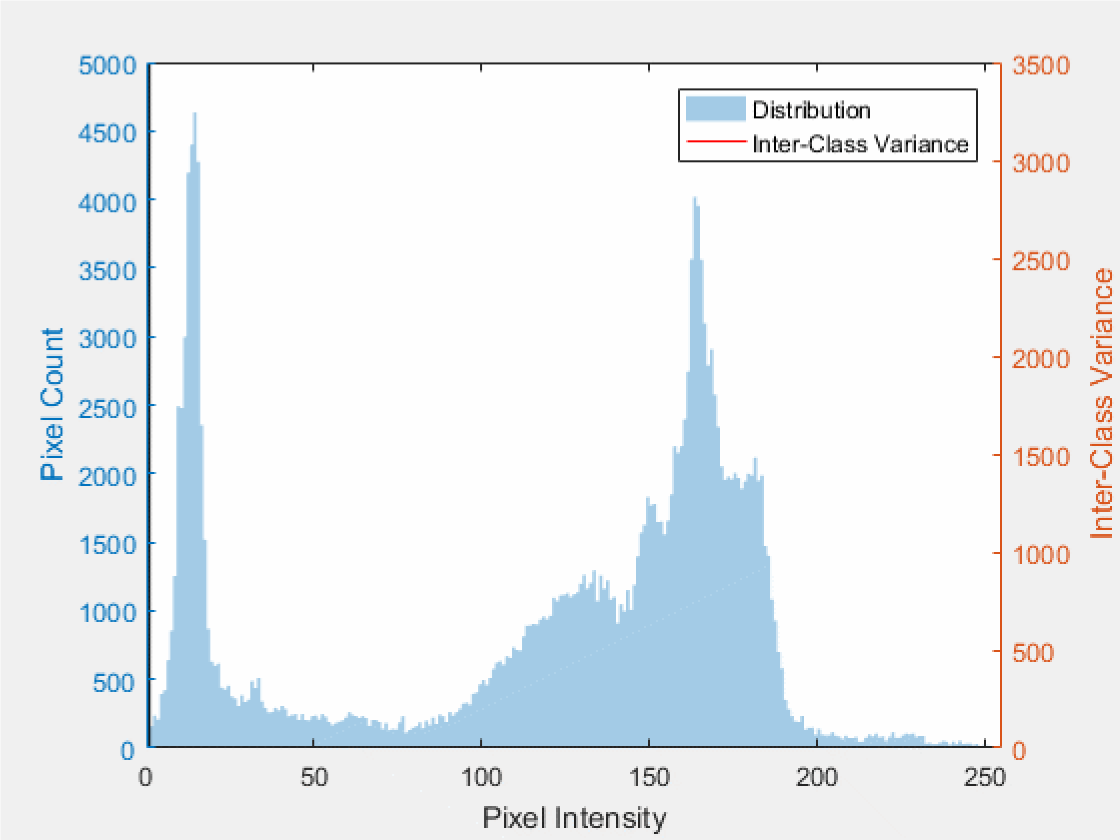
Algorithm

1. Compute histogram and probabilities of each intensity level
2. Set up initial $\omega_i(0)$ and $\mu_i(0)$
3. Step through all possible thresholds $t = 1, \ldots$ maximum intensity
    1. Update ω_i and μ_i
    2. Compute $\sigma_b^2(t)$
4. Desired threshold corresponds to the maximum $\boxed{\sigma_b^2(t) = \omega_0(t)\omega_1(t)[\mu_0(t) - \mu_1(t)]^2}$

$$\omega_0(t) = \sum_{i=0}^{t-1} p(i) \qquad \mu_0(t) = \frac{\sum_{i=0}^{t-1} ip(i)}{\omega_0(t)}$$

$$\omega_1(t) = \sum_{i=t}^{L-1} p(i) \qquad \mu_1(t) = \frac{\sum_{i=t}^{L-1} ip(i)}{\omega_1(t)}$$

Otsu’s Method



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