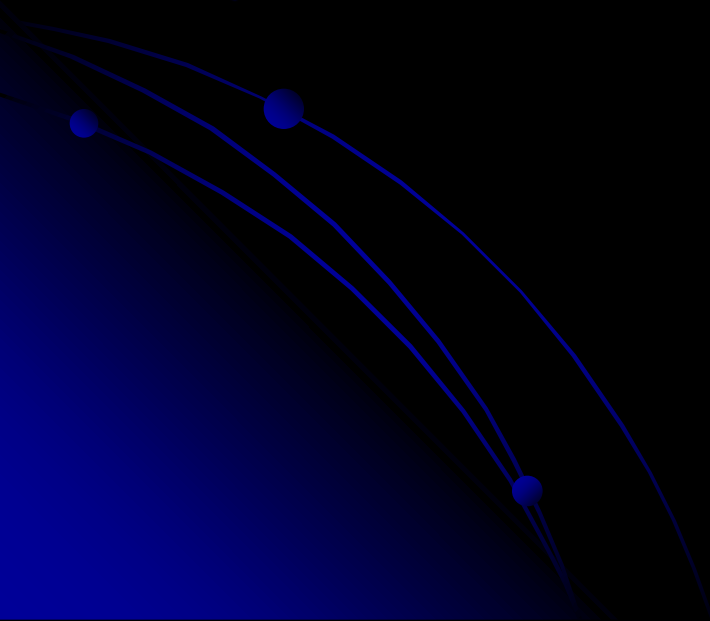


# CSSE463: Image Recognition

Day 21

- Sunset detector due.
- Foundations of Image Recognition completed
- This week:
  - K-means: a method of image segmentation
  - Template matching: a simple method for object detection
- Questions?



An image to segment...

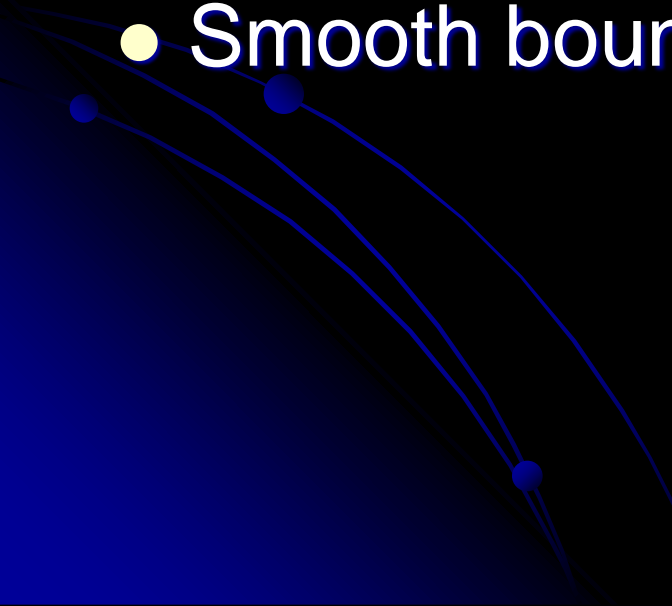


# Segmentation



- The process of breaking an image into regions.
- Two types:
  - General-purpose
    - “One size fits all”
    - Very difficult...
  - Specialized
    - Intended for a specific domain (say fruit-, circle- or skin-finding)
    - Can be successful
- One to right is created using the mean-shift algorithm
  - D. Comaniciu, P. Meer: Mean shift: A robust approach toward feature space analysis. *IEEE Trans. Pattern Anal. Machine Intell.*, **24**, 603-619, 2002.
  - EDISON code downloadable at <http://www.caip.rutgers.edu/riul/research/robust.html>

# What properties can we use to segment?

- Regions homogeneous wrt. color, texture, etc.
  - Simple interiors
  - Adjacent regions different (else merge)
  - Smooth boundaries
- 

# Approaches

## 1. Models

- Uses an expected shape, color, etc. (fruit- and circle-finders)
- Can use probabilities

## 2. Clustering

- An *unsupervised* machine learning technique
  - No class labels used in learning!
- Groups pixels “close” to each other by some metric.
  - Color distance, texture, intensity, spatial location, etc.
- Regions are then found using connected components

# K-means clustering

$$\min_C D = \sum_{k=1}^K \sum_{x_i \in C_k} \|x_i - m_k\|^2$$

- D= total distance
- K = # of clusters
- x are pixels
- $C_k$  is the set of pixels in cluster  $k$
- $m_k$  is the center of cluster  $k$
- $\|\cdot\|$  is a distance

- **Goal:** given K clusters, assign each pixel to one of the clusters such that the *total* distance from each pixel to the center of its cluster is minimized.
- We control C, the assignment of pixels to each cluster. (We will actually do this by specifying the location of their means)

# K-means clustering

$$\min_C D = \sum_{k=1}^K \sum_{x_i \in C_k} \|x_i - m_k\|^2$$

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## Problems:

- What's  $K$ ?
- How do we know which pixel belongs to each cluster?
- K-means is an answer to the second question.

# K-means clustering

- Iterative process to group into  $k$  clusters.
- Algorithm (Sonka, p 403; Forsyth&Ponce, p. 315; Shapiro, p. 282)
- Initialize  $k$  cluster means
- Repeat until convergence:
  - For each pixel, find the closest mean and assign it to that cluster
  - Re-compute the mean of all pixels assigned to the cluster
- Label each pixel with its current cluster
- Example on board using 2D spatial distance
- Could you implement?



# K-means clustering

- We are trying to find out where the clusters are and which points are assigned to each cluster. We iteratively solve half the problem. Notice the overall structure:

- Repeat until convergence:
  - **Assume you know where the cluster centers are.** For each pixel, find the closest mean and assign it to that cluster
  - **Assume you know which points belong to each cluster.** Recompute the mean of all pixels assigned to the cluster
- Label each pixel with its current cluster

# K-means clustering

- Pros:
  - Easy to implement
  - Finds local optimum
  - Global optimization (over all partitions) is infeasible
- Cons:
  - The number of clusters,  $k$ , must be known in advance
  - Some clusters might have 0 points
  - Local optimum is only an approximation
- Ideas:
  - Can re-run with several initializations
  - Can choose  $k$  based on observation or statistical means

# K-means clustering

$$\min_C D = \sum_{k=1}^K \sum_{x_i \in C_k} \|x_i - m_k\|^2$$

- $K$  = # of clusters
- $x$  are pixels
- $C_k$  is the set of pixels in cluster  $k$
- $m_k$  is the center of cluster  $k$
- $\|\cdot\|$  is a distance: could be 2D distance in image or **3D Euclidean distance between colors** (or combination of both)

(On Lab: will produce disconnected regions)

# K-means results



Original (120x160)



K=3



K=5



K=7