CS131
Foreground-Background Segmentation via Clustering

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Overview

- Use clustering algorithms to segment images
- Evaluate by segmenting cats out of images
- Not a lot of code! (< 100 lines)
- Focus on experimentation

Overall Flow

Prerequisite: Implement clustering algorithms

Input: an image

1. Compute a feature vector for each pixel
2. Cluster the feature vectors
3. Assign pixels to segments based on the clusters
4. Choose some subset of segments as "foreground"
5. Transfer foreground to another image
6. Compare foreground with ground truth

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Clustering Algorithms

You need to implement 2 clustering methods:

- K-Means Clustering
  - `KMeansClustering.m`
  - Covered in Lecture 13
- Hierarchical Agglomerative clustering
  - `HAClustering.m`
  - Covered in Lecture 12

Section 2 of assignment

Clustering Algorithms: Interface

```
function idx = KMeansClustering(X, k, visualize2D)
function idx = HAClustering(X, k, visualize2D)
```

`X`: Matrix where each row is a point

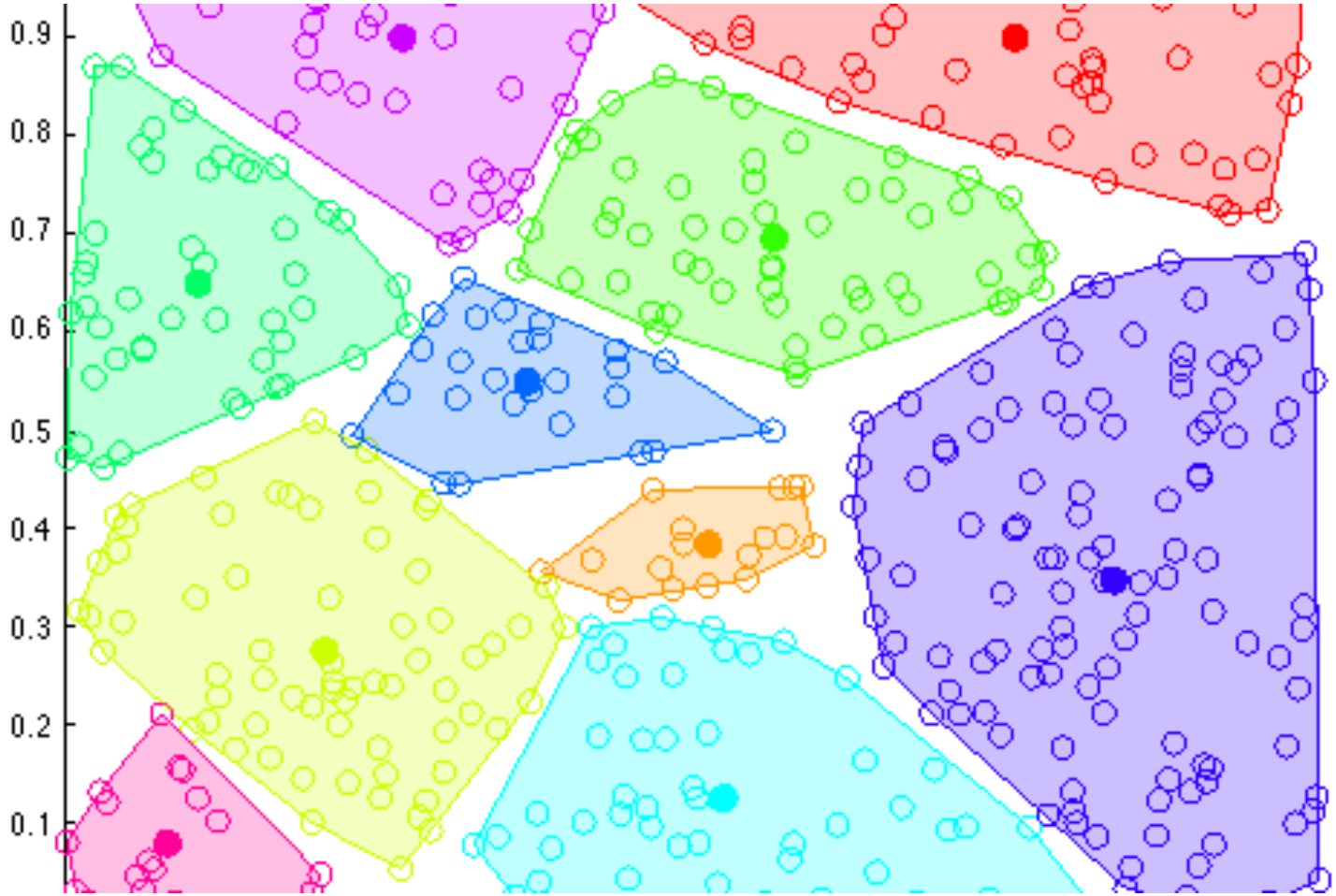
`k`: Number of clusters

`visualize2D`: If clustering 2D points, set this to true to see a visualization

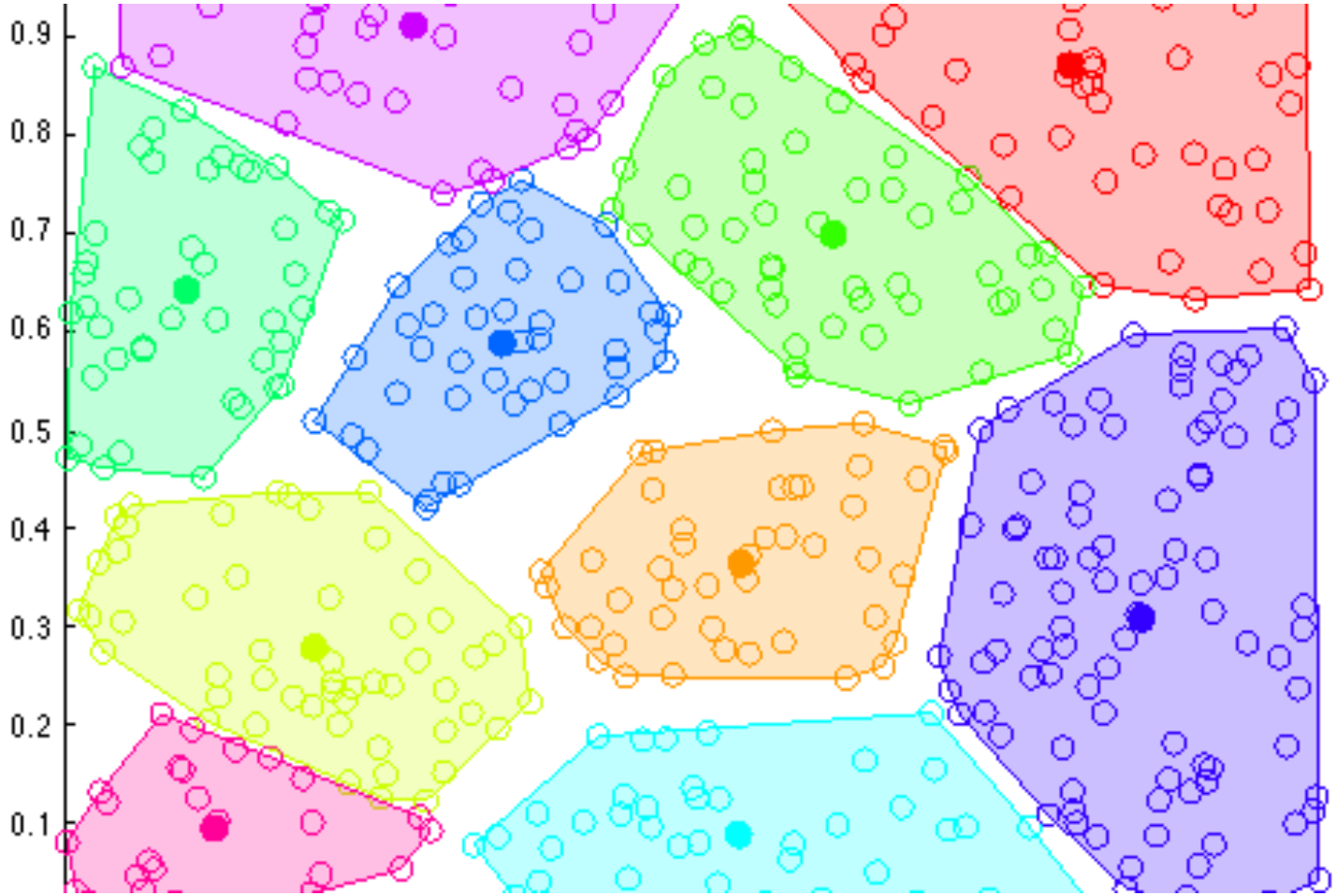
`idx`: Vector giving computed assignments of points to clusters

Note: `KMeansClustering` has an additional parameter `centers` that you don't need to worry about

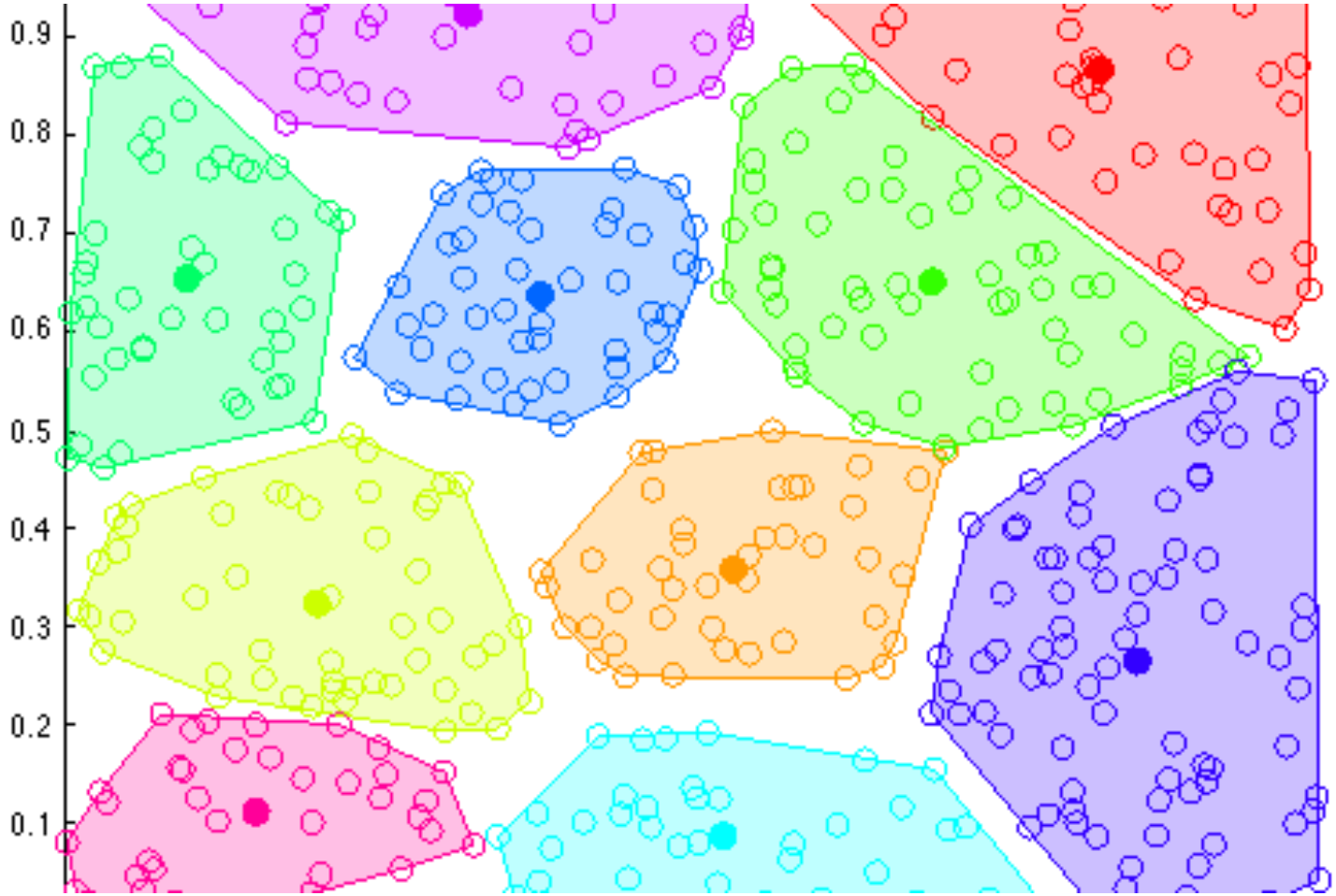
K-Means Clustering



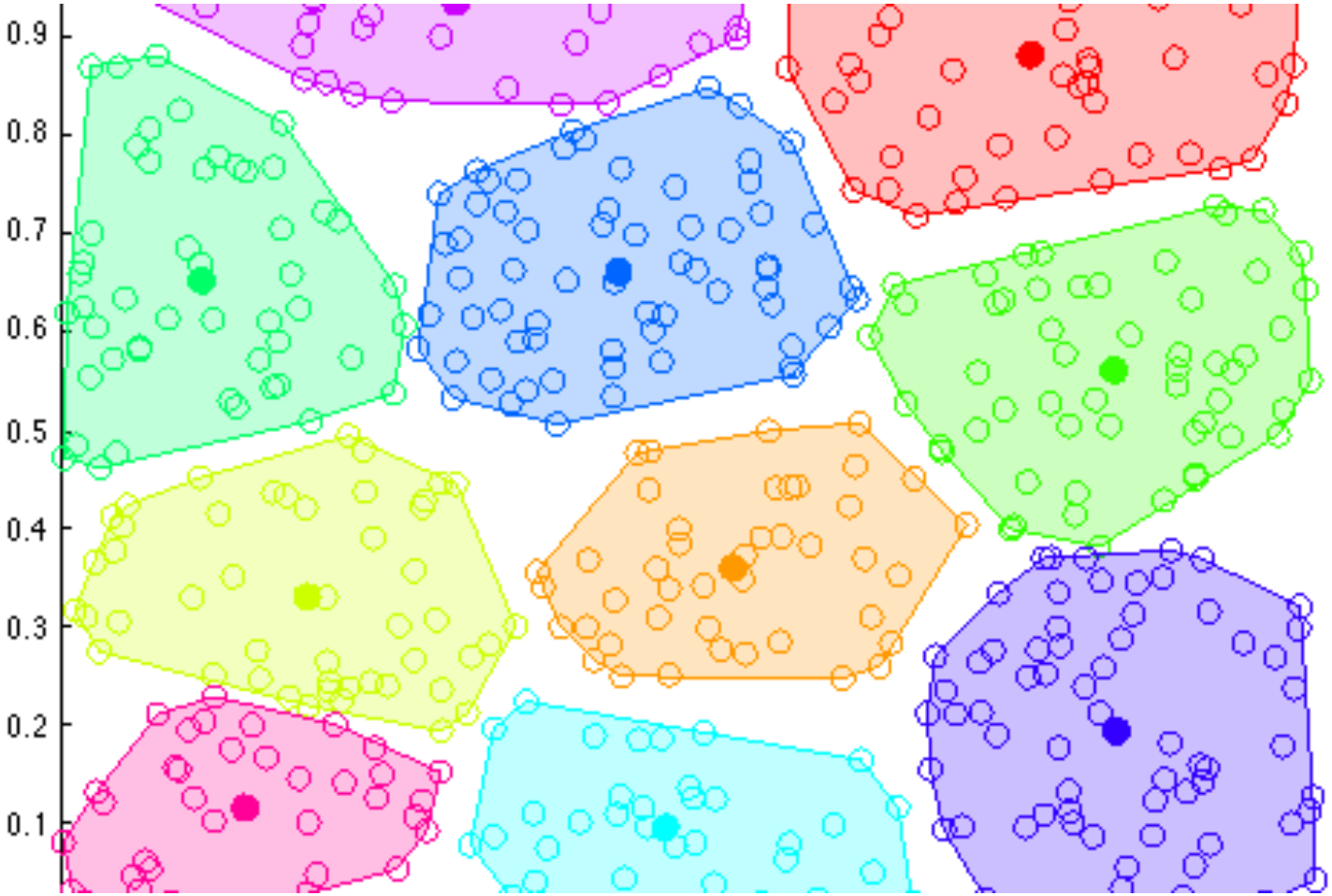
K-Means Clustering



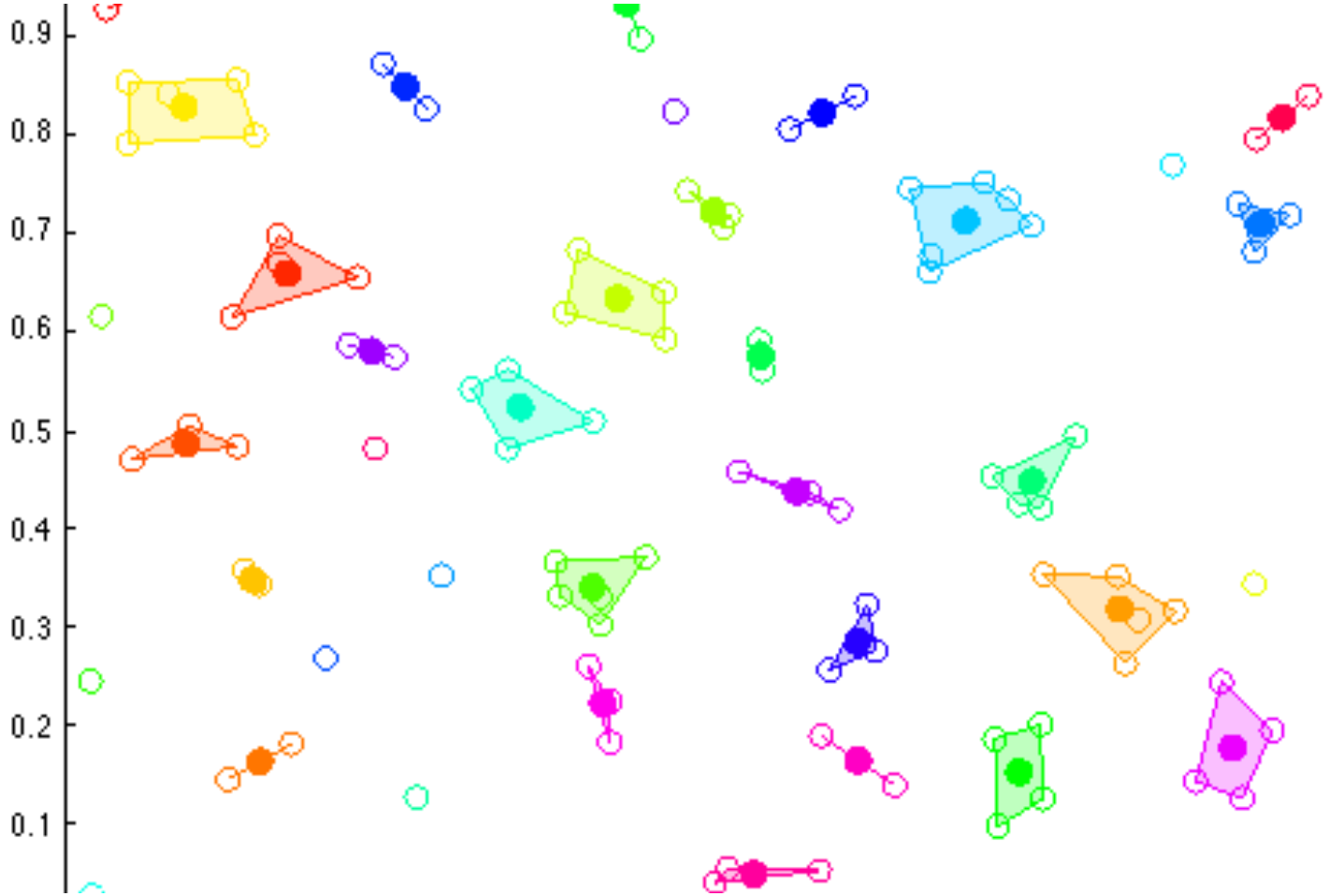
K-Means Clustering



K-Means Clustering

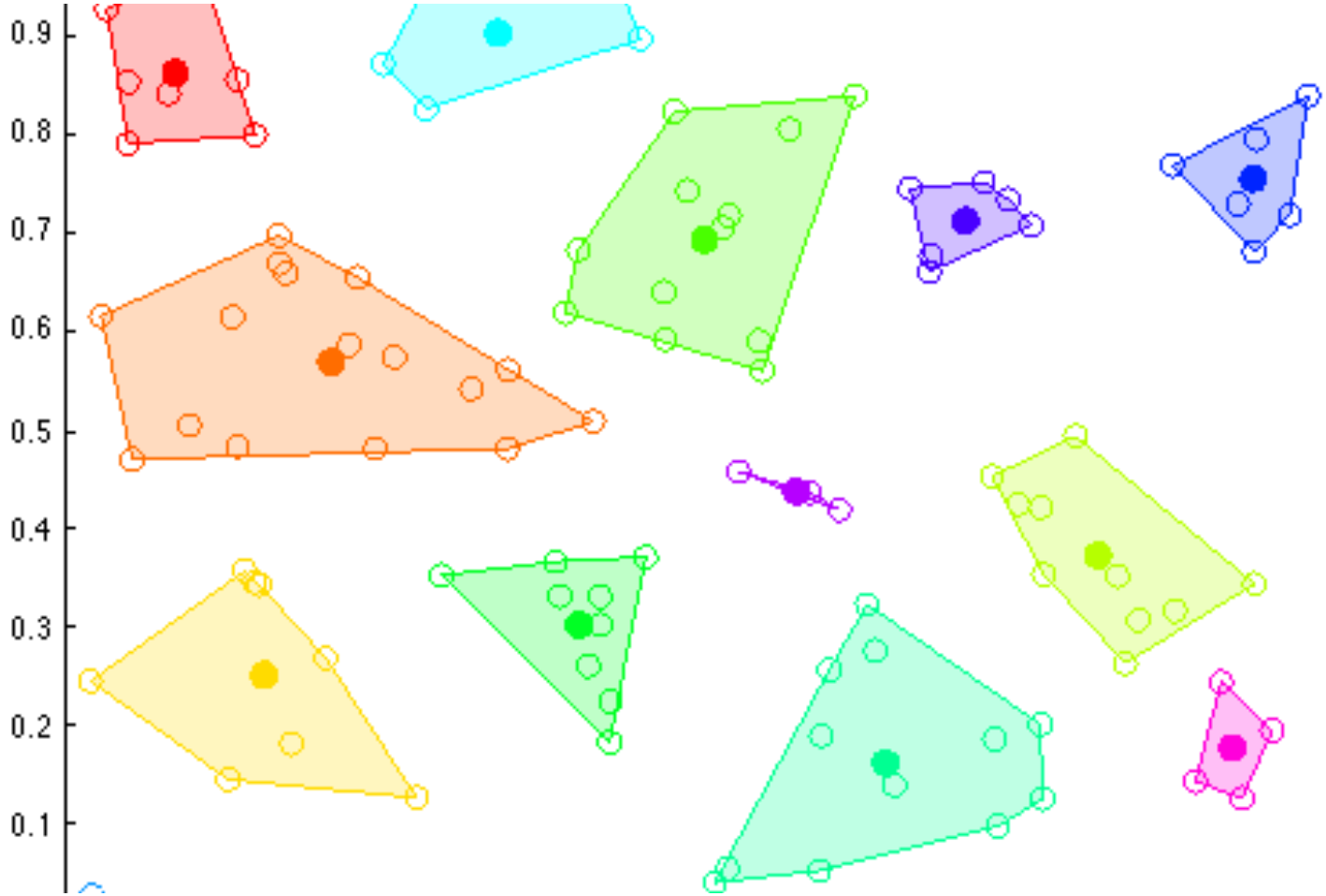


Hierarchical Agglomerative Clustering

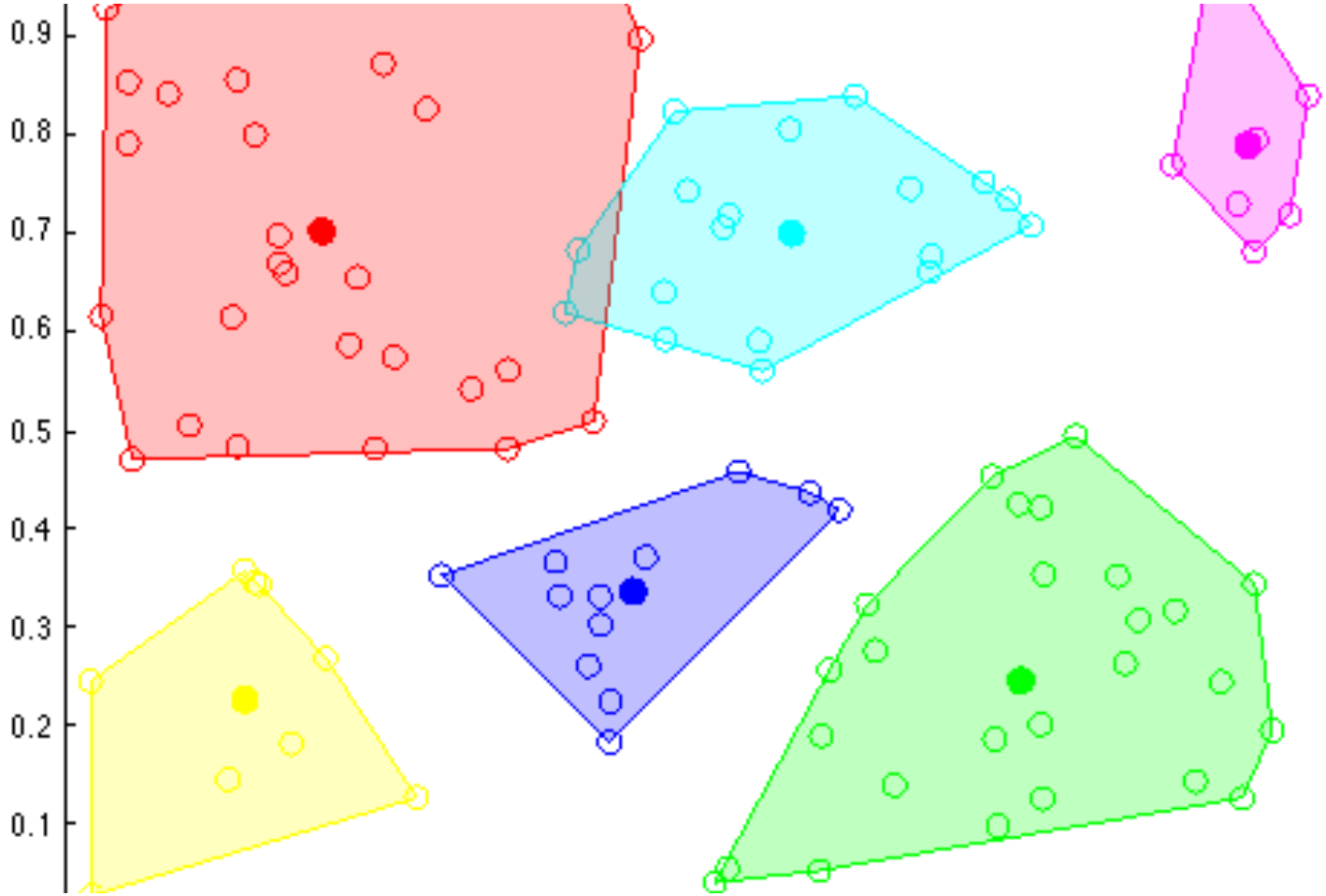


Hierarchical Agglomerative Clustering

Hierarchical Agglomerative Clustering



Hierarchical Agglomerative Clustering



Clustering: Efficiency Matters!

- For loops are SLOW in MATLAB; avoid them wherever possible!
- Useful MATLAB functions: `min, mean, pdist2, ind2sub, randperm`
- `HAClustering.m`:
  - Your code can be written with no for loops
  - For reference: clustering 5000 5D points on my laptop (3 year old MBP) takes about 90 seconds
- `KMeansClustering.m`
  - For reference: clustering 5000 5D points on my laptop takes < 1 second

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Pixel Feature Vectors

You need to at least two types of features:

- Color features: (r, g, b)
  - Done for you
  - `ComputeColorFeatures.m`
- Color and position features: (r, g, b, x, y)
  - You need to implement this
  - `ComputePositionColorFeatures.m`

Pixel Feature Vectors: Normalization

- Normalization is applied to feature vectors before clustering as a preprocessing step
- There are many types of normalization
- For this assignment we will normalize each feature to have **zero mean** and **unit variance:**

$$\mu_j = \frac{1}{n}\sum_{i=1}^{n} f_{ij} \qquad \sigma_j^2 = \frac{1}{n-1}\sum_{i=1}^{n}(f_{ij} - \mu_j)^2$$

$$\tilde{f}_{ij} = \frac{f_{ij} - \mu_j}{\sigma_j}$$

Pixel Feature Vectors: Extra Credit

Implement your own feature vectors and see how they perform

Some ideas:

- Gradients
- Edges
- SIFT descriptors

Use `ComputeFeatures.m` as a starting point

Pixel Feature Vectors: Interface

```
function features = ComputeColorFeatures(img)
function features = ComputePositionColorFeatures(img)
```

`img`: `h x w x 3` matrix of pixel data for image

`features`: `h x w x d` matrix of features for each pixel

Any custom feature vectors you write should have the same interface!

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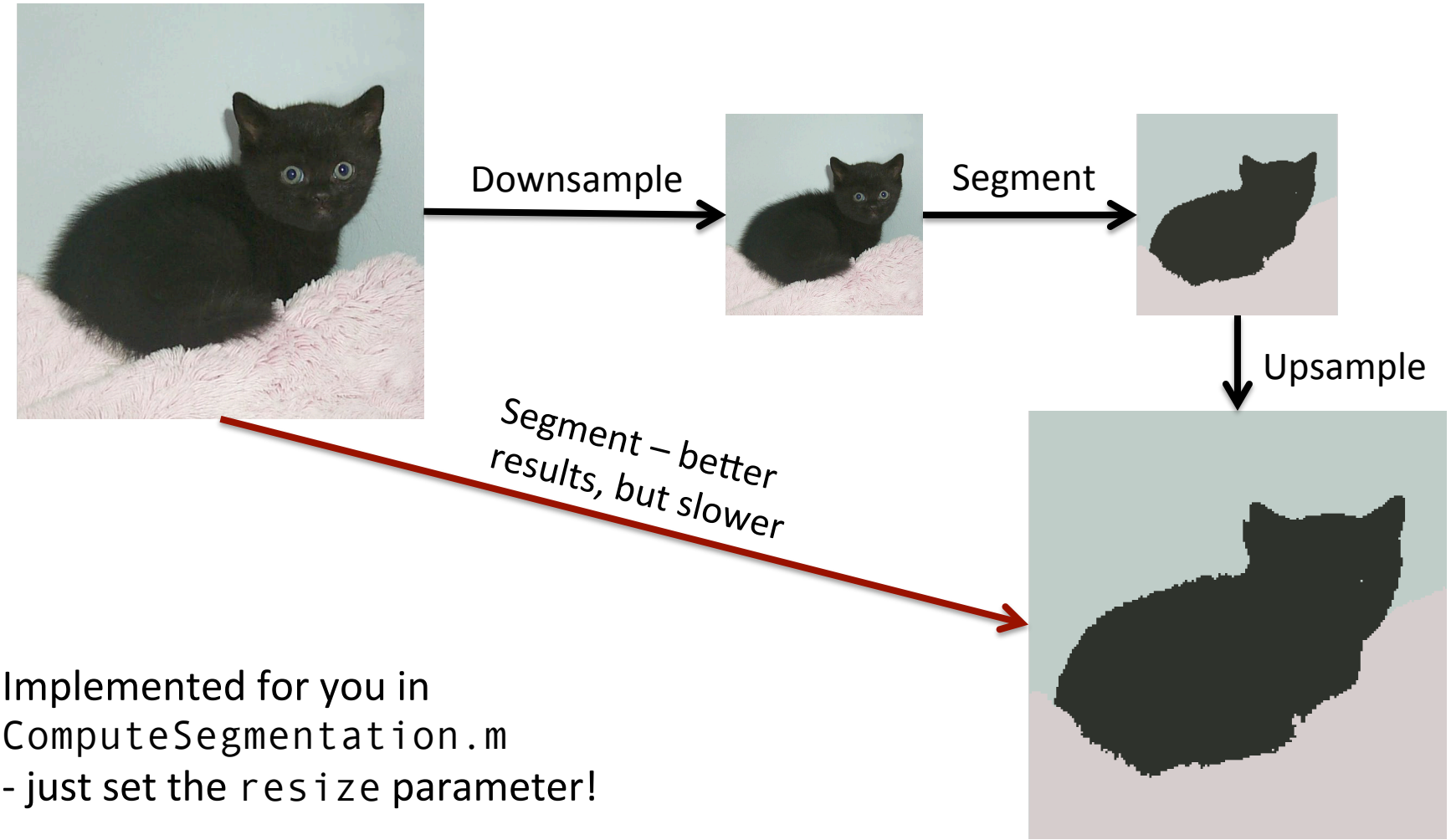
Cluster Feature Vectors + Assign Pixels

- This is done for you in `ComputeSegmentation.m` and `MakeSegments.m`
- `ComputeSegmentation.m` has many tunable parameters – read the documentation in the file!
- The data structure used to store a segmentation is described in `MakeSegments.m`
- Use `RunComputeSegmentation.m` as a starting point for your custom feature vectors

Resizing to Speed up Segmentation



Implemented for you in
`ComputeSegmentation.m`
- just set the `resize` parameter!

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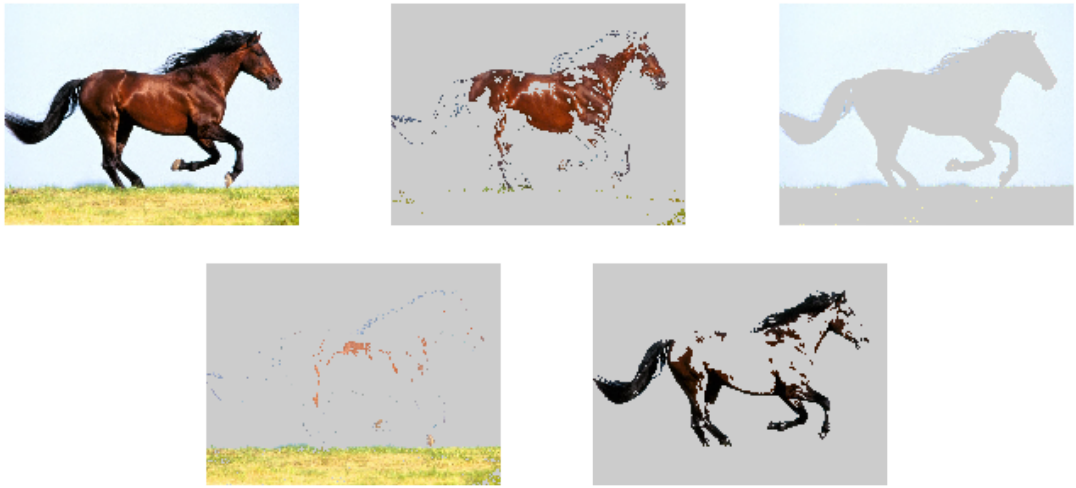
Choose Foreground Segments

- After segmenting an image, foreground object may be split across several segments
- Use `ChooseSegments.m` to pick a subset of segments as foreground



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Transfer Foreground

- Just use `ChooseSegments.m` but pass in a background image

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Compare with Ground Truth

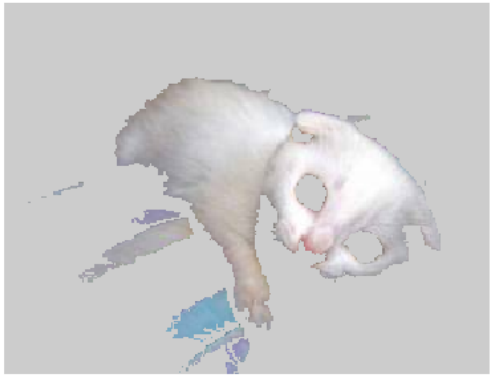
- We provide a small dataset of 17 pictures of cats with correct segmentations
- The accuracy of a segmentation is the fraction of pixels that are correctly labeled as foreground / background
- `EvaluateSegmentation.m` computes the accuracy of a segmentation
- Use `EvaluateAllSegmentations.m` as a starting point to evaluate your method on all images in the dataset

Compare with Ground Truth

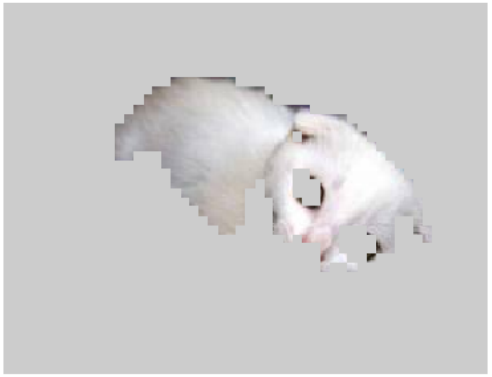
Original image

Ground truth segmentatio

Kmeans segmentatior
(Accuracy = 0.8877)



HAC segmentatior
(Accuracy = 0.8784)



What to do in writeup

- Answer all questions from the "In your Writeup" sections
- Focus on experimentation
  - Vary the segmentation parameters: feature transform, feature normalization, clustering algorithm, number of clusters, resize
  - How do your results change? (Qualitatively and quantitatively)