Segmentation as Clustering

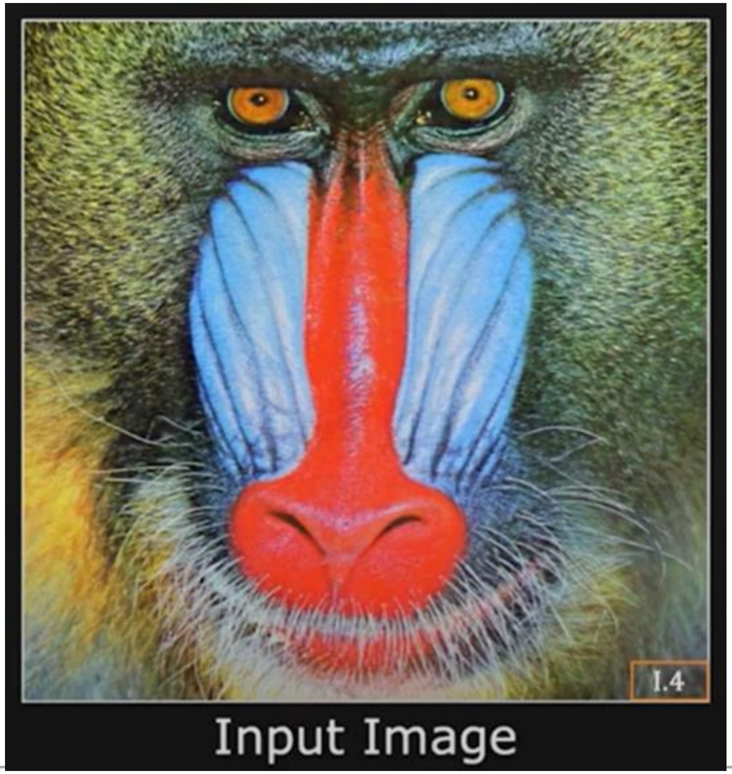
K-Means Clustering

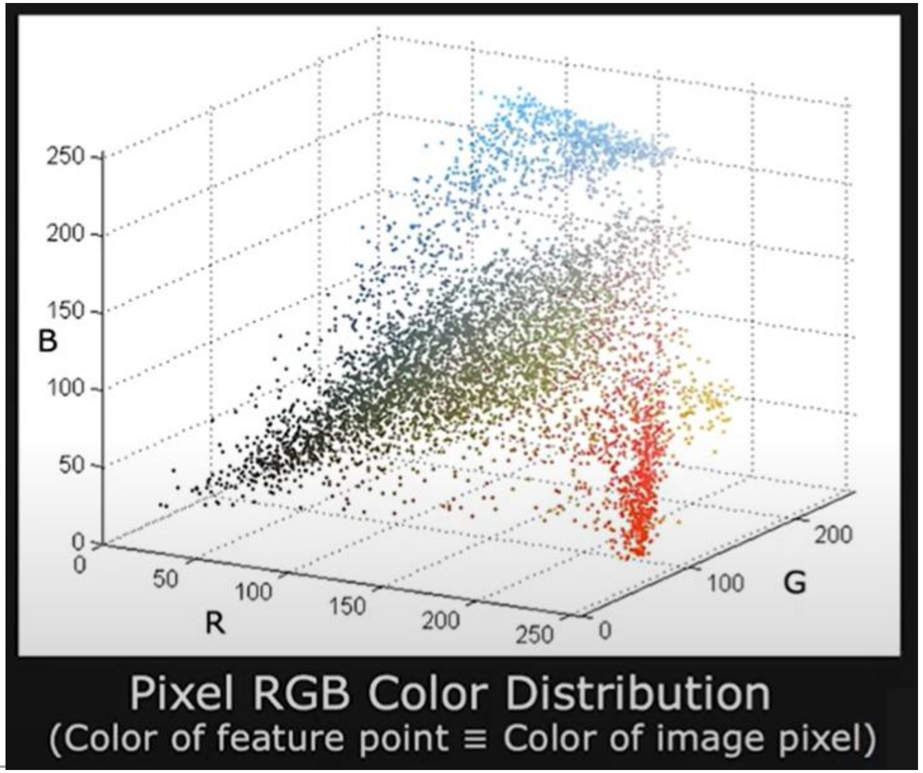
Visual Similarity

- Intensity
- Color
- Position
- Depth
- Motion
- Texture etc.

Pixels in Euclidean Space

- Euclidean Space: Generalization of 3D Cartesian space to higher dimensions.





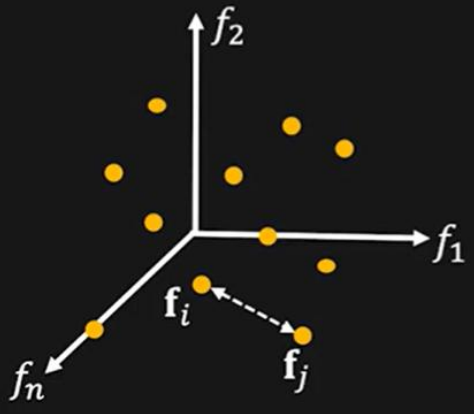
Pixels as feature vector: [R, G, B, x, y, d, ...]

Pixel Similarity

Let i and j be two pixels whose features are $\mathbf{f}_i$ and $\mathbf{f}_j$.

$\mathcal{L}^2$ Distance between $\mathbf{f}_i$ and $\mathbf{f}_j$:

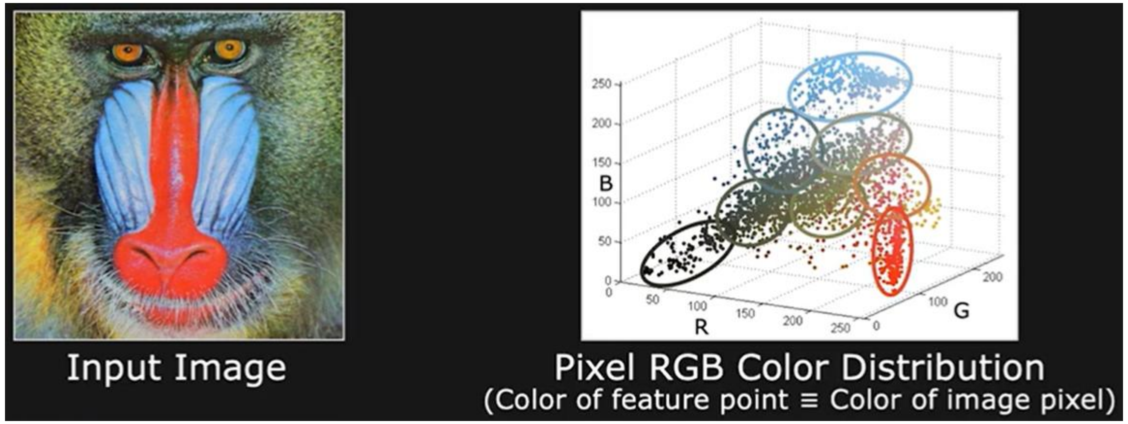
$$S(\mathbf{f}_i, \mathbf{f}_j) = \sqrt{\sum_k (f_{ik} - f_{jk})^2}$$

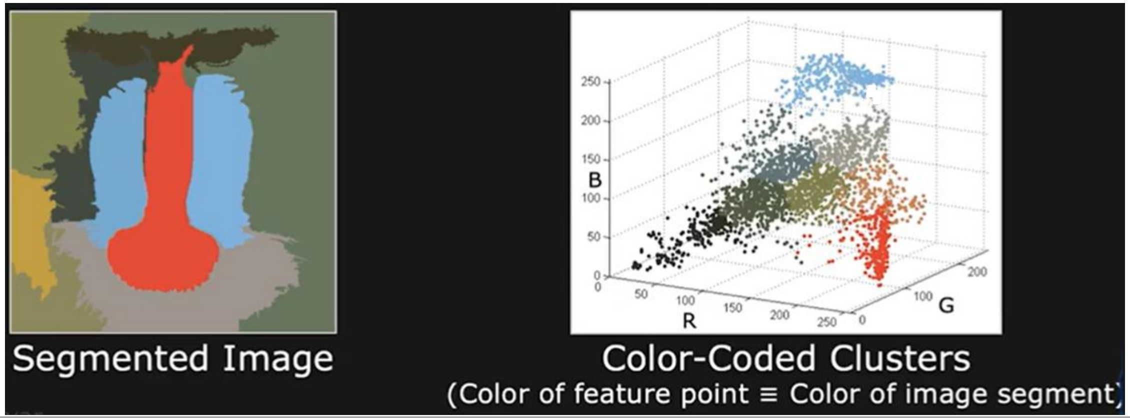


$[R, G, B, x, y, \ldots]$-space

Smaller the Distance, Greater the Similarity

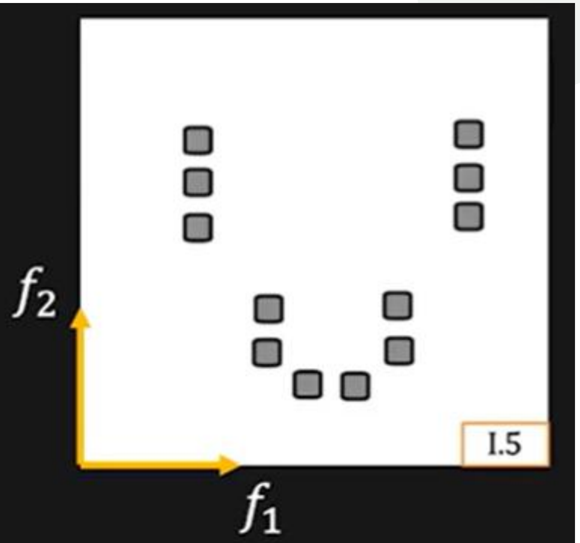
Clustering Similar Pixels





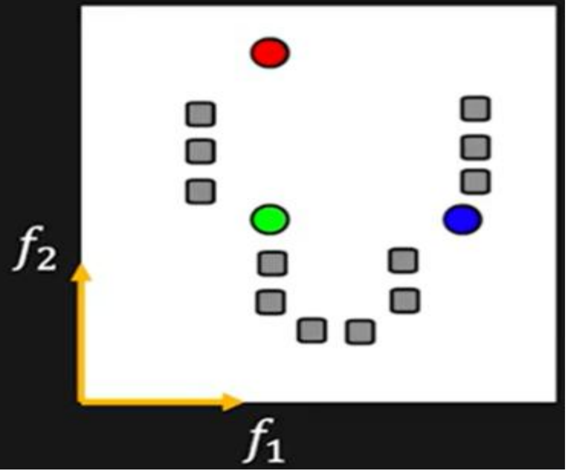
3-Means Clustering

Problem: Segment the given pixel feature distribution into 3 clusters.



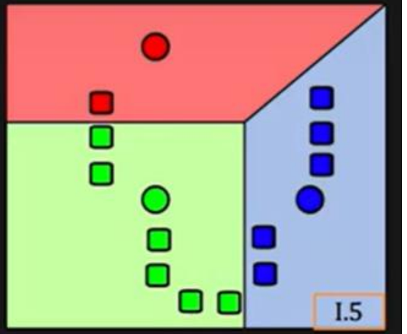
Solution:

Step 1: Randomly generate the initial centroids (means) of the 3 clusters.

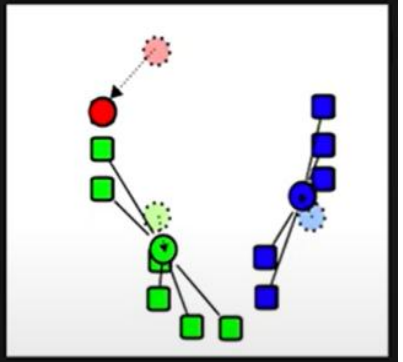


3-Means Clustering

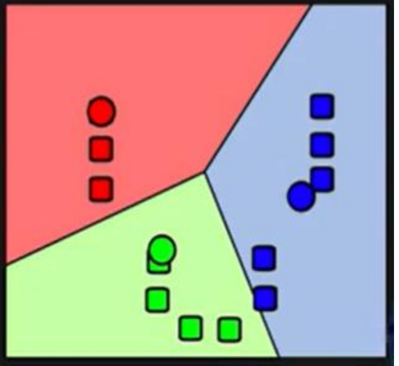
Step 2: Create 3 clusters by assigning each feature point to the nearest mean.



Step 3: Recompute the mean of each cluster.



Step 4: Repeat steps 2 and 3 until convergence.



K-Means Clustering

Given: Image with N pixels and number of clusters k.

Task: Find the k clusters.

Clustering:

1: Pick k points randomly as the initial centroids (means) $\{\mathbf{m}_1, \mathbf{m}_2, \ldots, \mathbf{m}_k\}$ of the k clusters in feature space.

2: For each pixel $\mathbf{x}_j$ find nearest cluster mean $\mathbf{m}_i$ to pixel's feature $\mathbf{f}_j$ and assign pixel to cluster i.

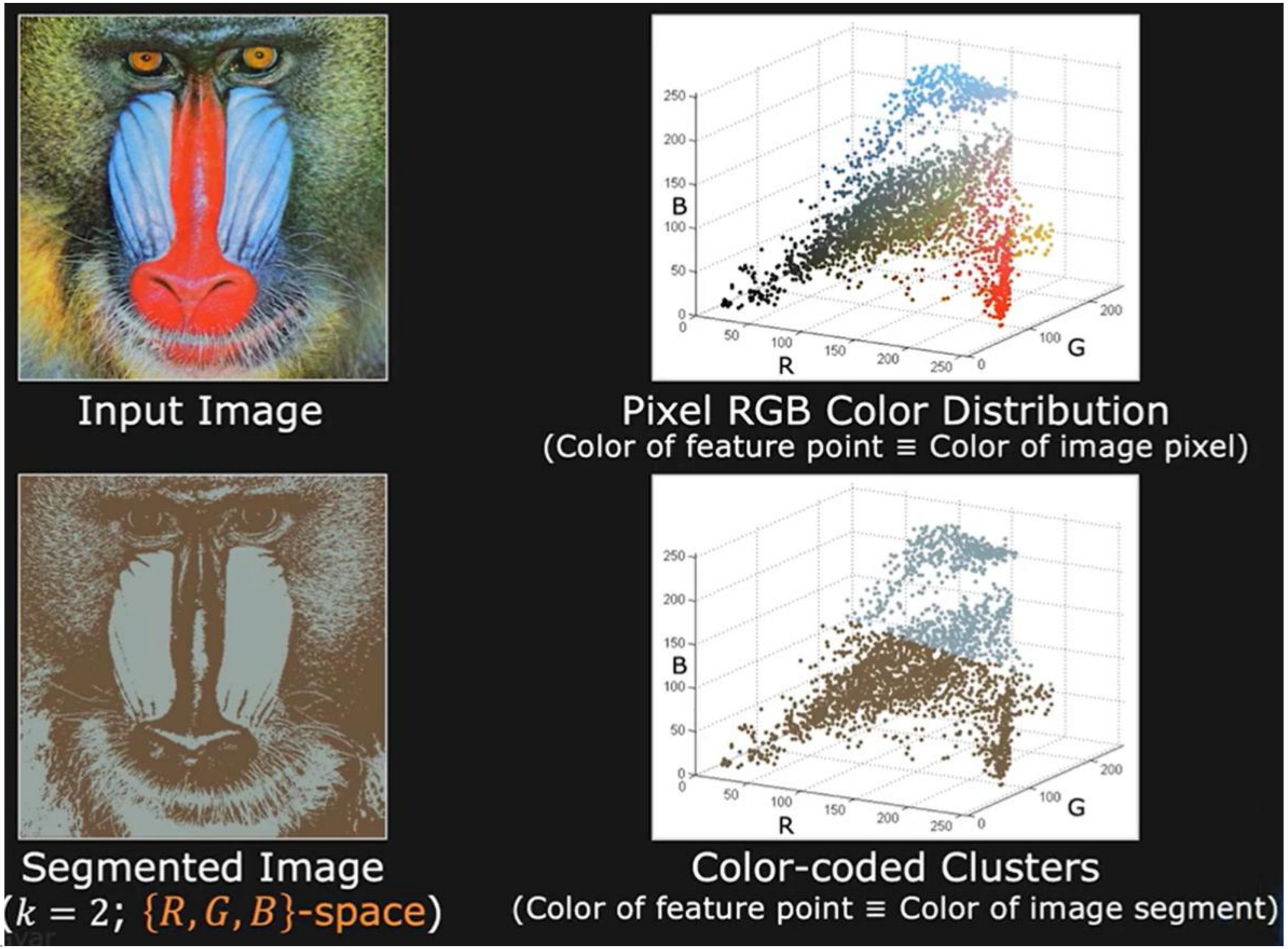
3: Recompute mean for each cluster using its assigned pixels.

4: If changes in all k means is less than a threshold ε, stop. Else go to step 2.

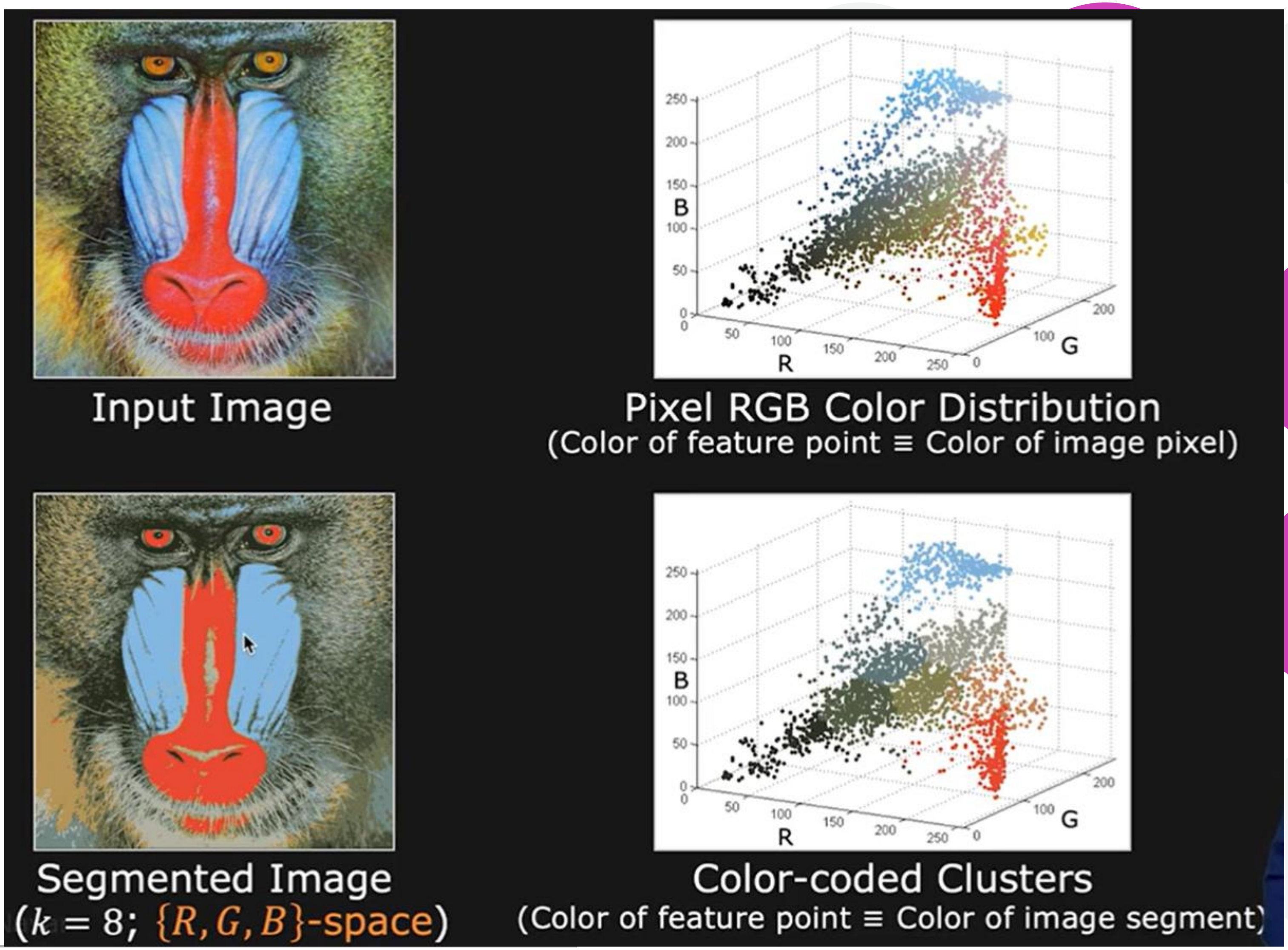
K-Means Initialization methods

- Method 1: Select k random feature points as initial centroids. If two points are very close, resample.
- Method 2: Select k uniformly distributed means within the range of distribution.
- Method 3: Perform k-means clustering on a subset of pixels and use the result as the initial means.

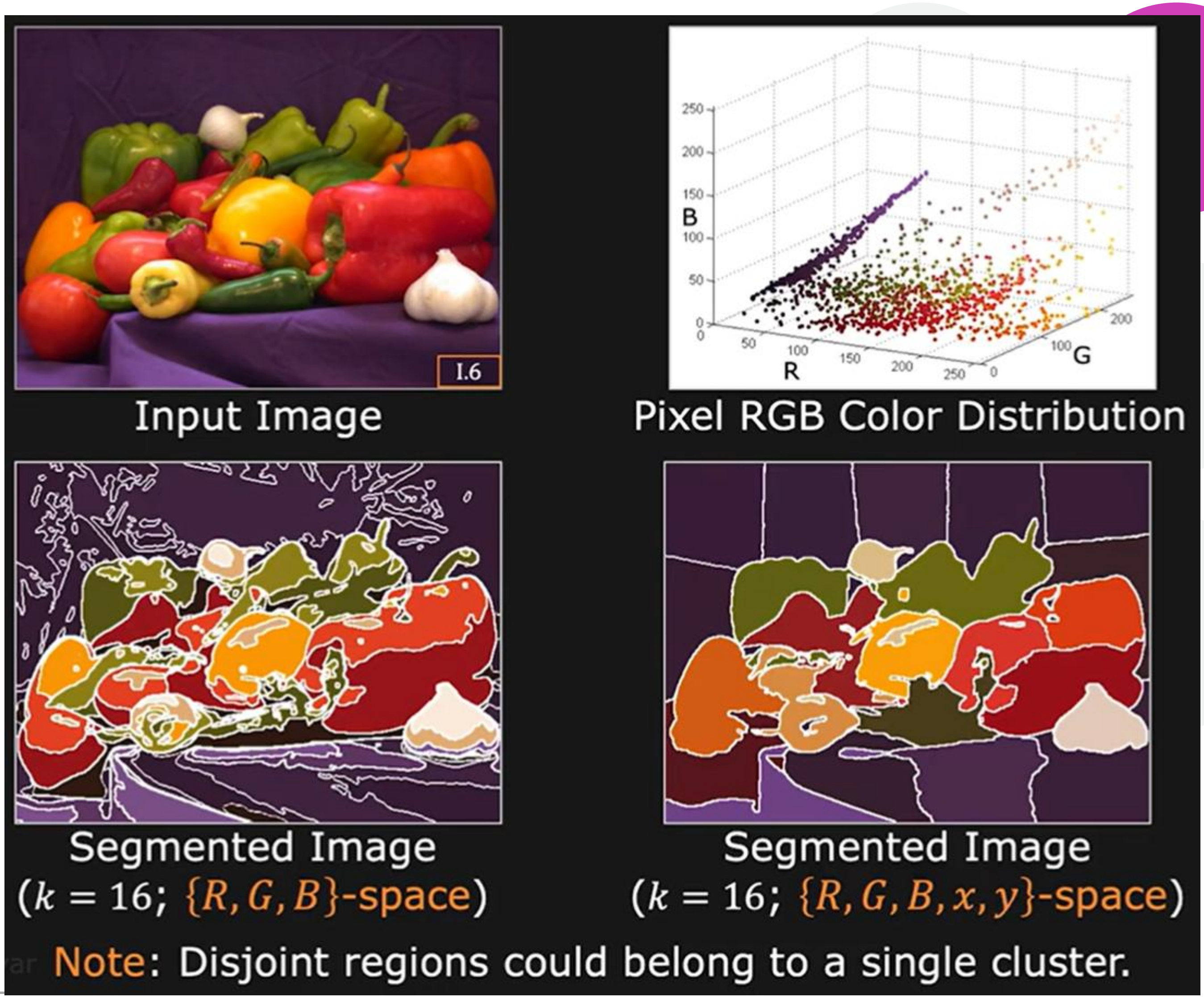
K-Means Clustering Results (k=2)



K-Means Clustering Results (k=8)



K-Means Clustering Results (k=16)



K-Means Clustering: Remarks

- Simple and reasonably fast

- Need to pick the number of clusters k
- Sensitive to initialization
- Sensitive to outliers