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CV Assignment 2

Introduction

Question asks to:

1. Load images from directory.
2. Resize images to (64, 64).
3. Apply k-means clustering to segment images for 3 and 6 clusters.
4. Apply ratio-cut algorithm to segment images for 3 and 6 clusters.
5. Compare the results.

Implementation details for ratio-cut algorithm

1. **Calculate adjacency matrix:** each pixel in image is treated as vertex. So we have 64*64 = 4096 pixels. Edge Weights are the pixel affinities. The adjacency matrix values are edge weights between two pixels. Therefore, adjacency matrix is symmetric matrix of shape (4096, 4096).

   Pixel_affinity = exp[- pixel_dissimilarity / 2*(sigma^2)]

   Pixel_dissimilarity = $||I_k - I_j||_2^2$ + lambda * $||x_k - x_j||_2^2$

2. **Calculate degree matrix:** it calculates connectivity of each vertex with each other.
3. **Calculate laplacian matrix:** laplacian matrix = degree matrix - adjacency matrix.
4. **Calculate eigenvectors of laplacian matrix:** eigenvectors of the laplacian matrix contain the spectral information. Selecting the first k eigenvectors from the decomposition gives the most informative and necessary feature matrix.
5. **Apply K-means clustering algorithm:** Apply the k-means clustering algorithm to the selected eigenvectors to partition the image into the desired number of clusters, leveraging the spectral properties of the Laplacian matrix for clustering analysis.

Below are the results for all 4x2 cases:

Image 1 - 3 clusters

image1 3 clusters kmeans

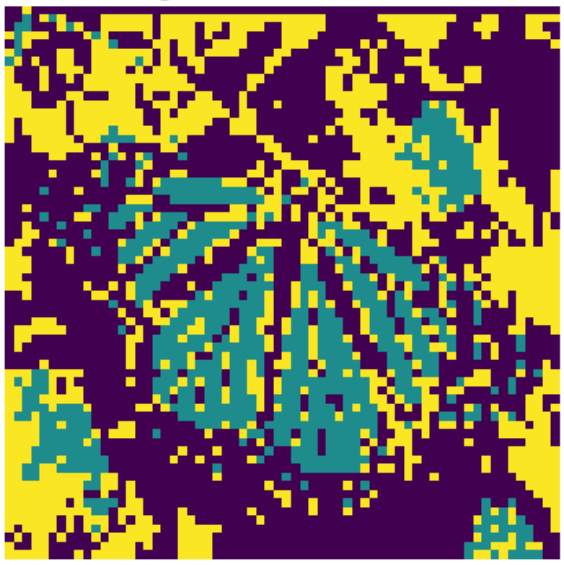


image1

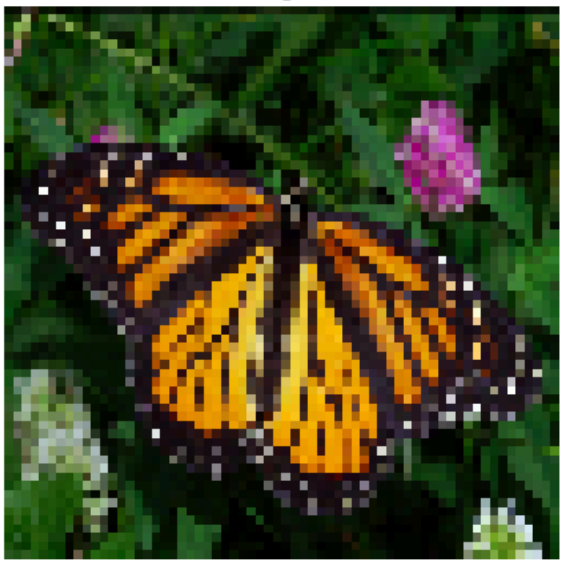


image1 3 clusters ratio cut

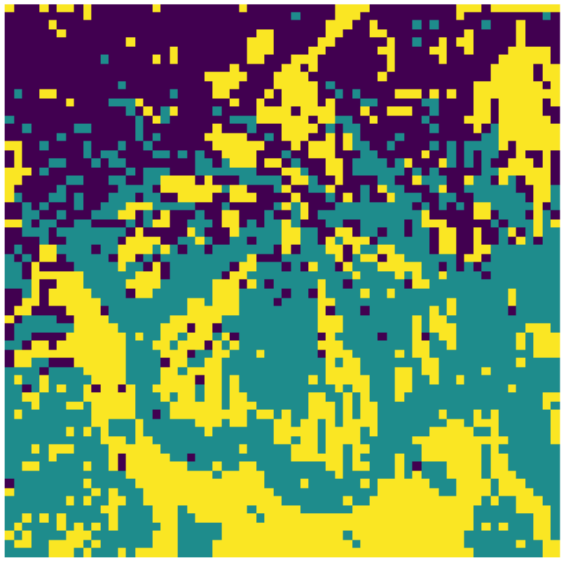


image1

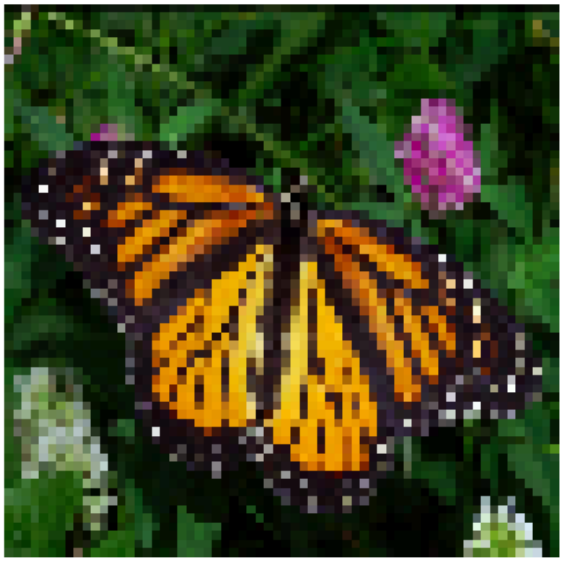


Image 1 - 6 clusters

image1 6 clusters kmeans

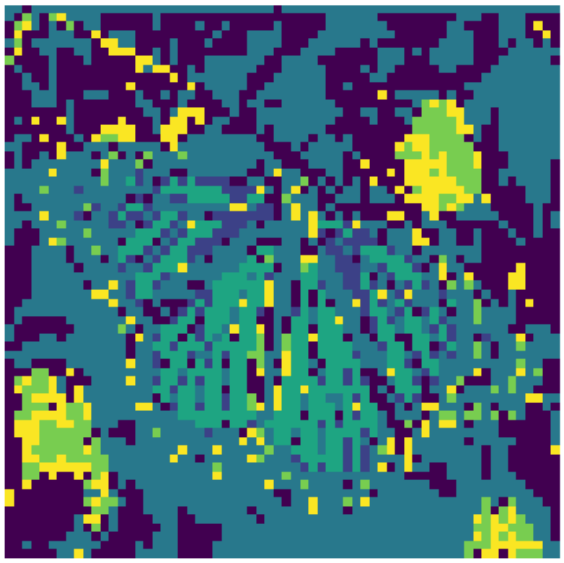


image1

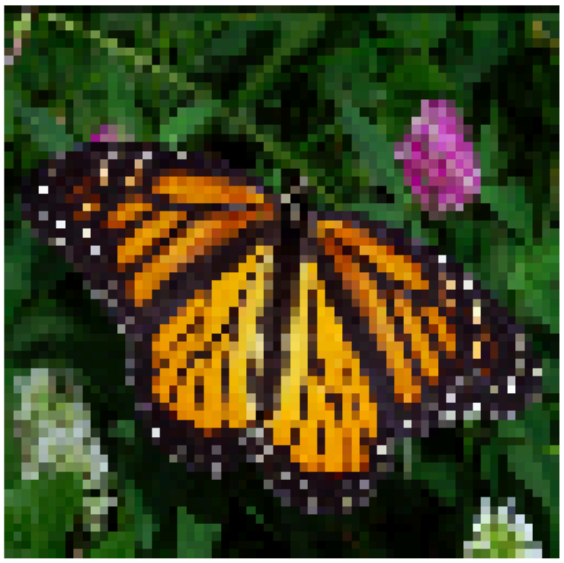


image1 6 clusters ratio cut

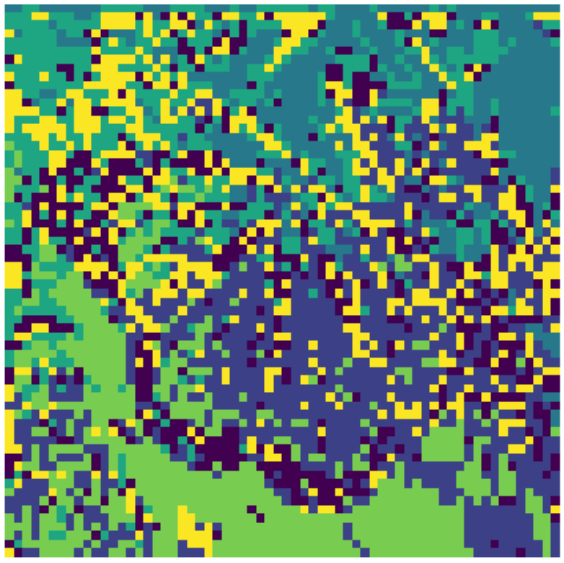


image1

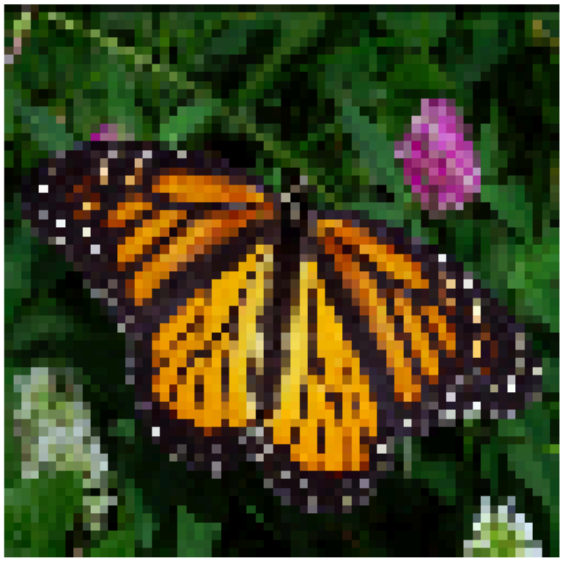


Image 2 - 3 clusters

image2 3 clusters kmeans

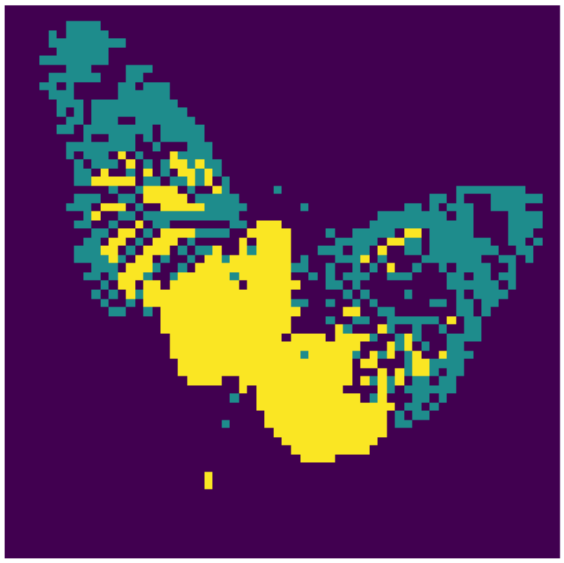


image2

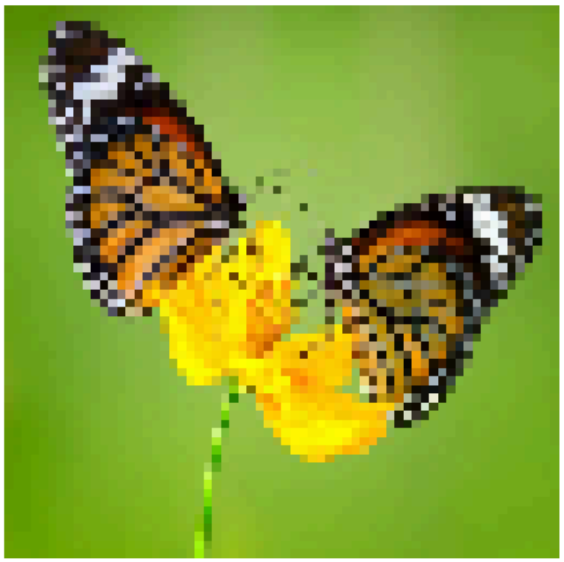


image2 3 clusters ratio cut

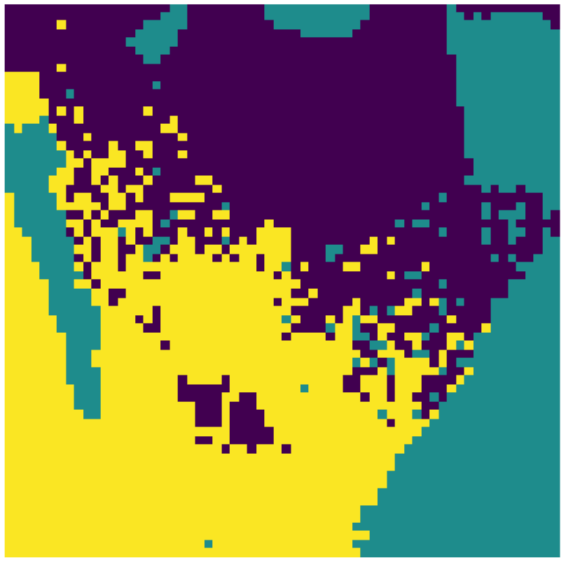


image2

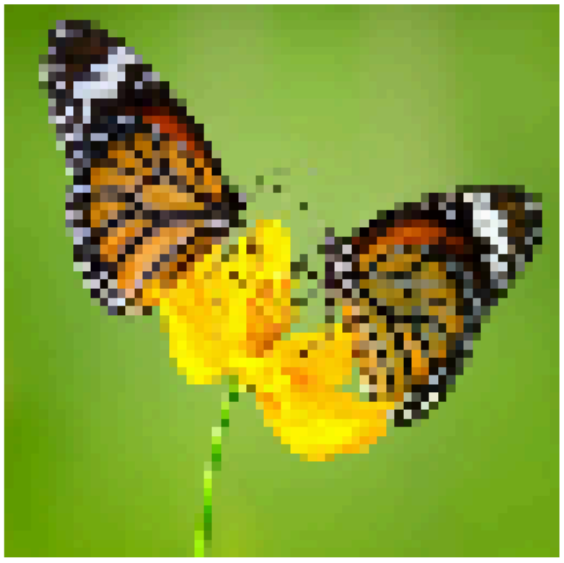


Image 2 - 6 clusters

image2 6 clusters kmeans

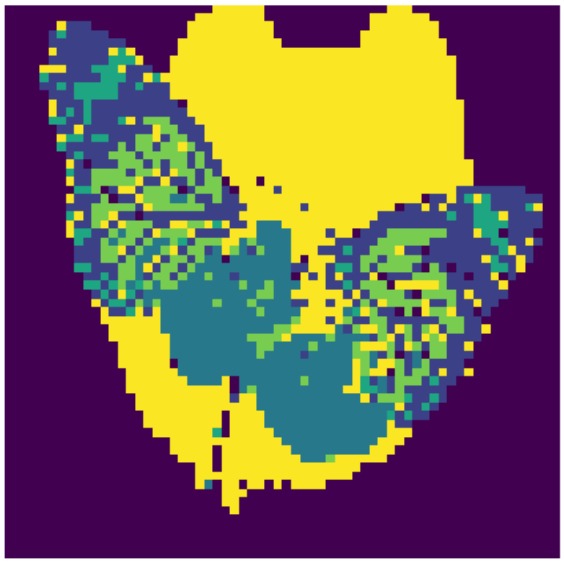


image2

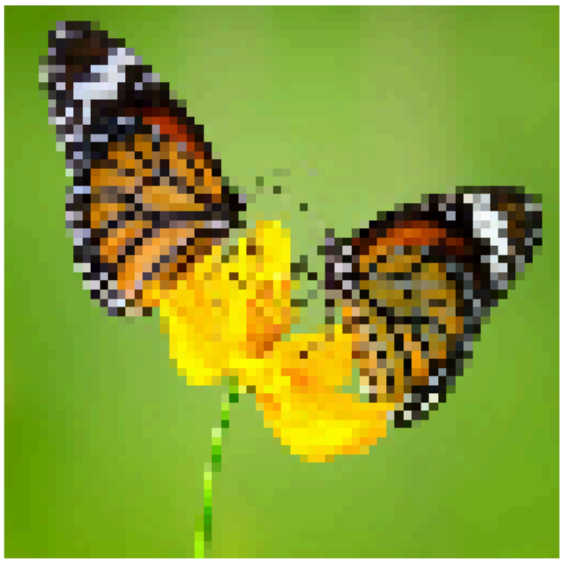


image2 6 clusters ratio cut

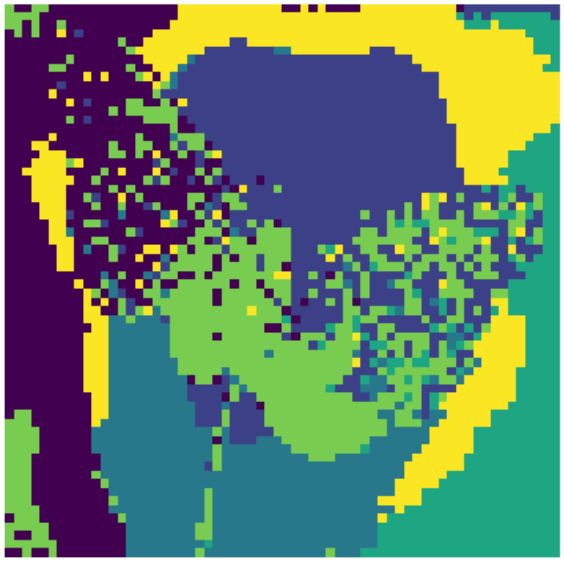
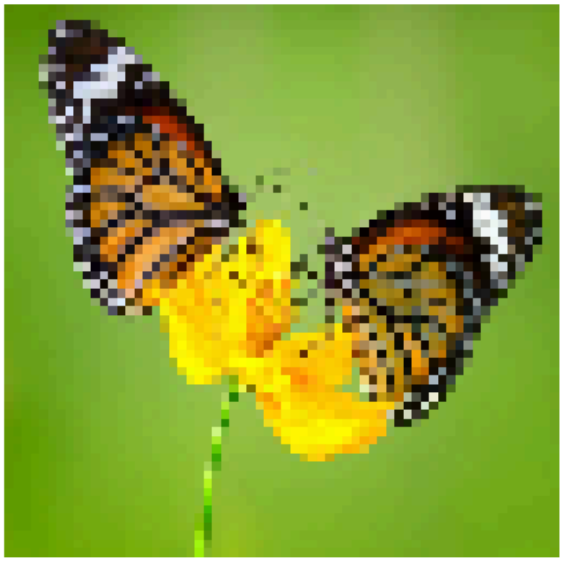


image2



Observations

1. **Computational Efficiency:** K-means clustering has faster computation as compared to the ratio-cut. This is because ratio-cut requires calculation of adjacency matrix which requires computation between every pixel in image. This is roughly half of squared of number of pixels in terms of computations. Then we need to calculate eigenvectors of laplacian matrix, which itself is another computationally heavy operation. Then we apply k-means itself on eigenvectors subset which is roughly equally computational to whole k-means clustering method.
2. **Segmentation Results:** K-means clustering is visually more accurate than ratio-cut algorithm. K-means tends to cluster pixels with similar color together even if they belong to different objects. Whereas ratio-cut tries to put pixels of same object together but optimizing the hyperparameters for accurate results is very difficult.
3. **Cluster comparisons:** increasing the number of clusters gave better results for each image because 3 clusters are possibly less to capture sufficient spectral information, therefore increasing clusters to 6 helps to capture more spectral information for both algorithms. Increasing upto certain threshold of clusters would still optimize the results because 6 clusters are also not sufficient.