

E9 246 Advanced Image Processing

Assignment 2

Due Date: 22/02/2026

General Instructions:

- You may use Google Colab or a local GPU setup. You are free to use any open-source deep learning libraries (e.g., PyTorch, TensorFlow).
 - Along with your code, submit a brief report with all results and key observations.
 - Place all files into a single zip file and submit it. Name the zip file as `AIP2_YourName`.
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1 Graph-Based Image Segmentation using Normalized Cuts (8+4+8 = 20)

In this problem, you will study perceptual grouping using the Normalized Cut (N-Cut) framework and analyse the effect of affinity design and partitioning strategies. Please use the dataset available here for the entire question.

- (a) The original Normalized Cuts paper defines the affinity between pixels i and j as:

$$w_{ij} = \exp\left(-\frac{\|I(i) - I(j)\|^2}{\sigma_I^2}\right) \exp\left(-\frac{\|X(i) - X(j)\|^2}{\sigma_X^2}\right),$$

where $I(i)$ denotes the pixel intensity (or feature value) and $X(i)$ denotes the spatial location. Consider the following modified affinity function:

$$w_{ij} = \exp\left(-\frac{\|I(i) - I(j)\|^2}{\sigma_I^2}\right) \exp\left(-\frac{\|X(i) - X(j)\|^2}{\sigma_X^2}\right) \exp\left(-\frac{E_{ij}^2}{\sigma_E^2}\right),$$

where E_{ij} represents the edge strength or gradient magnitude between pixels i and j . Implement N-Cut using both the original affinity and the modified edge-aware affinity. Apply both affinities on at least two images and present the segmentation results. Visually compare the results and explain how the modified affinity affects region separation, particularly near strong boundaries.

- (b) Using the affinity functions from part (a), perform N-Cut segmentation for different values of the parameters σ_I and σ_X . Analyze the effect of varying σ_I while keeping σ_X fixed. Also analyze the effect of varying σ_X while keeping σ_I fixed. Discuss the impact on over-segmentation, under-segmentation, and boundary localization.
- (c) Read the original Normalized Cuts paper and implement segmentation into more than two regions. Implement multi-way segmentation using a recursive two-way N-Cut approach. Also implement multi-way segmentation using simultaneous partitioning (e.g., by using multiple eigenvectors). Compare the results obtained from the two approaches in terms of perceptual quality and region consistency. Compare the two multi-way segmentation strategies.

2 Semantic Segmentation with Different Decoder Designs (7+7+6=20)

In this problem, you will analyze how decoder design influences dense prediction performance in semantic segmentation. Please use the dataset available here for the entire question. Use ResNet18 as an encoder for semantic segmentation

- (a) Design a decoder that performs a single-stage upsampling directly from the deepest encoder feature map to the input image resolution. Use transposed convolution layer for upsampling. Do not use intermediate feature maps from the encoder.
- (b) Design a second decoder that performs progressive upsampling in multiple stages. Introduce skip connections from two different depths of the encoder.
- (c) Quantitatively evaluate pixel-wise accuracy and mean Intersection-over-Union (mIoU). Qualitatively analyse the segmentation outputs with emphasis on boundary sharpness. Discuss the role of progressive upsampling and skip connections in dense prediction tasks.