Bishop's University

CS563-463 Fall 2025

Computer Vision-Image processing

Instructor: Dr. Elmehdi Aitnouri

E-mail: eaitnour@ubishops.ca

Final Project Mean Shift

1. Identification

Name: Mean Shift

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Team members

Last name	First name	ID	Email
Rafiee	Masoud	002342935	mrafiee22@ubishops.ca
Tayeb Cherif	Zouina Sonia	002352786	ztayeb23@ubishops.ca

2. Problem Definition

The objective of this project is to implement the Mean Shift algorithm for both image Filtering (Smoothing) and image Segmentation. Mean Shift is a non-parametric clustering technique that iteratively shifts data points towards the densest regions. In image processing this allows smoothing while preserving edges and grouping pixels into coherent regions. The program must handle both grayscale (PGM) and color (PPM) image files.

3. Methodology

File Handling: Images are loaded using PIL and converted to NumPy arrays. The results are saved automatically in a RESULTS folder.

Libraries Used:

- **NumPy:** Numerical computation.
- **PIL:** Image loading and saving.
- **Matplotlib:** Visualization.
- **OS / Sys:** File handling and program control.

Feature Space:

- Grayscale images: 3D feature space (intensity + spatial coordinates).
- Color images: 5D feature space (RGB + spatial coordinates).

3.1. Program overview

This Program is implemented in Python and, at runtime, the program performs the following steps:

1. Prompts the user to enter the image file name.
2. Allows the user to choose between image filtering (smoothing) or image segmentation.
3. It requests the user for parameters (hs and hr) for Filtering and (hs, hr and M) for Segmentation
4. Displays the original and processed image side by side and saves the resulting image in a newly created RESULTS folder.

3.2. Mean Shift Filtering (Smoothing)

Mean Shift Filtering smooths the image while preserving edges by iteratively shifting each pixel toward the local density maximum in the combined spatial-range feature space. This process is guided by Kernel Density Estimation using two bandwidths:

- **Spatial bandwidth (*hs*):** defines the neighborhood size in the image plane.
- **Range bandwidth (*hr*):** defines similarity in intensity or color space.

Each pixel is updated by computing the weighted mean of nearby pixels within these bandwidths, producing a smoothed image that reduces noise without blurring edges.

3.3. Mean Shift Segmentation

Segmentation builds on filtering, the image is first smoothed using Mean Shift filtering to reduce noise.

- After filtering, pixels are clustered into regions using flood-fill region growing.
- Regions smaller than M pixels are eliminated by merging with the most similar neighbor.

4. Results and Discussion

4.1. Filtering Results

Grayscale (image1.pgm):

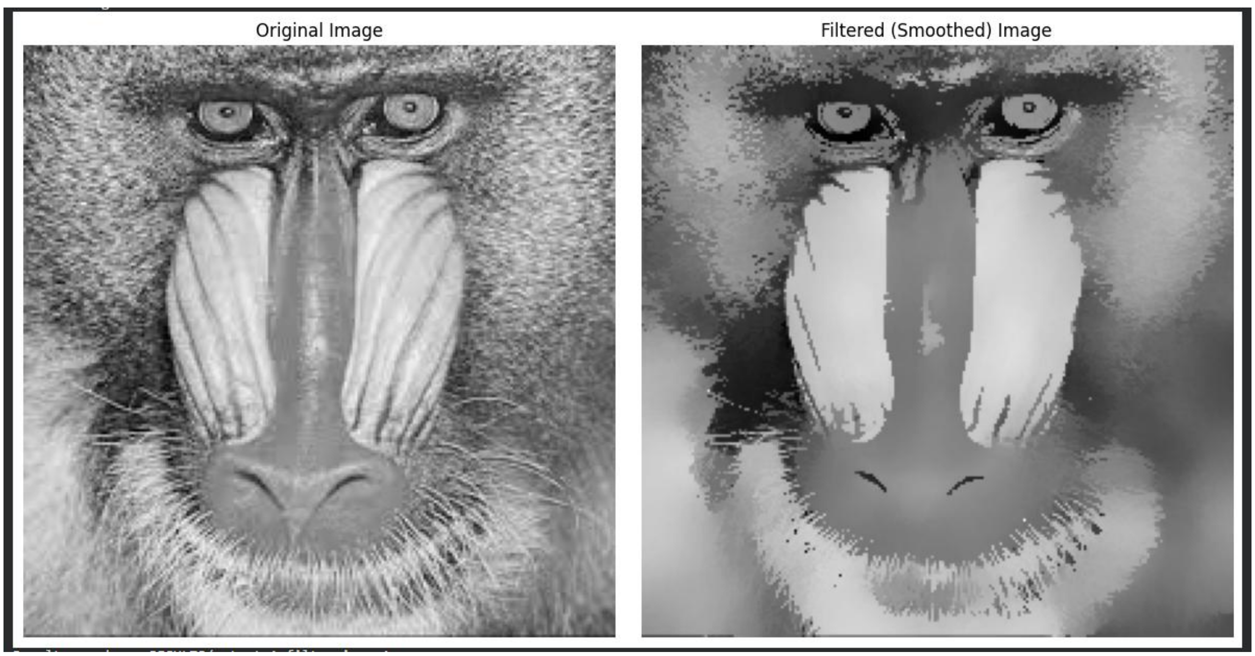
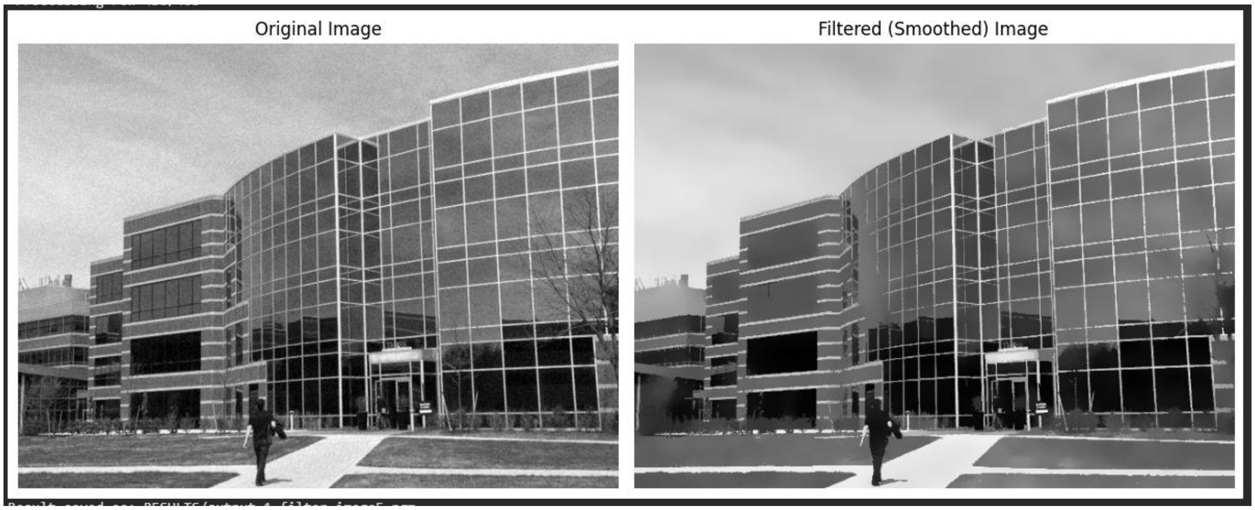


Image1.pgm presents a challenging test case due to its intricate fur texture and fine intensity variations across the face. Using a spatial bandwidth of hs = 10 and range bandwidth of hr = 22 during filtering, the mean shift algorithm effectively reduced noise while preserving important structural details. As shown in the filtered result, high-frequency noise in the fur regions is significantly smoothed, while prominent edges such as the nose contours, facial ridges, and eye boundaries remain sharp. This result demonstrates the strength of Mean Shift as an edge-preserving smoothing technique. Although some fine texture details are softened during the smoothing process, the algorithm maintains a good balance between noise reduction and feature preservation, producing a visually coherent image.

Grayscale Image (image5.pgm) :



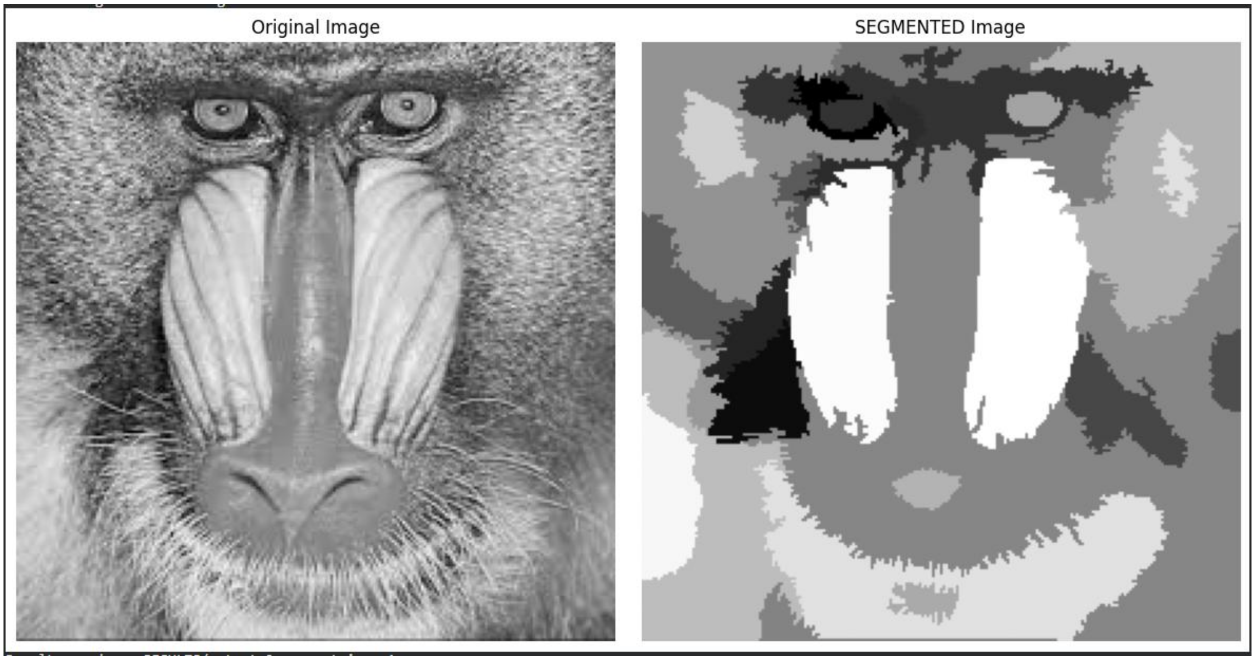
This image is another example of grayscale filtering.

Color Image (image8.ppm):

The algorithm significantly reduced color noise and small variations in image8.ppm. Large regions such as the sky and water appear smoother while major scene structures remain visible. This confirms the algorithm’s ability to perform edge-preserving smoothing on color images.

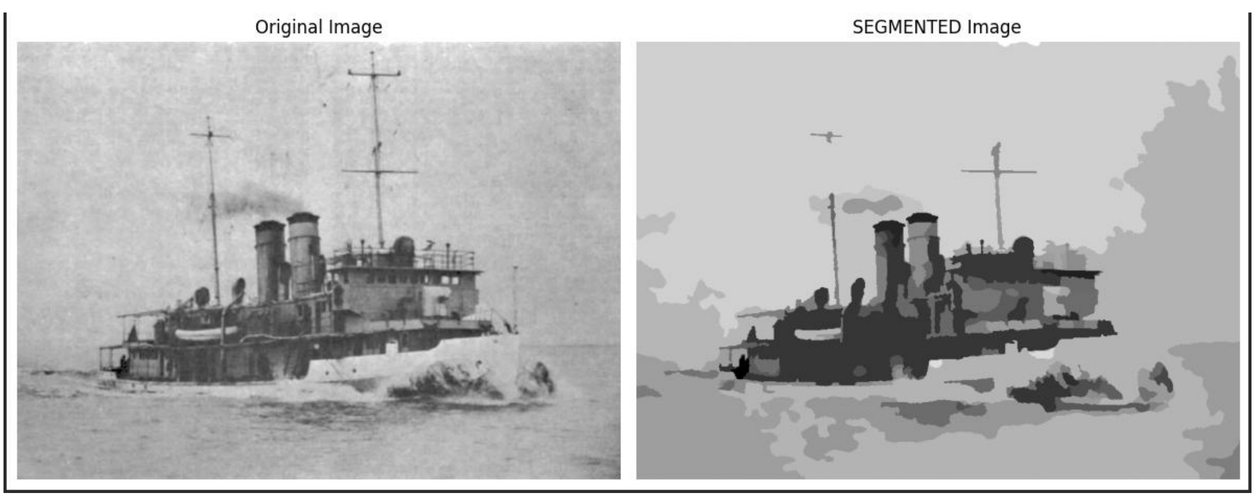
4.2. Segmentation Results

Grayscale Image (image1.pgm) :



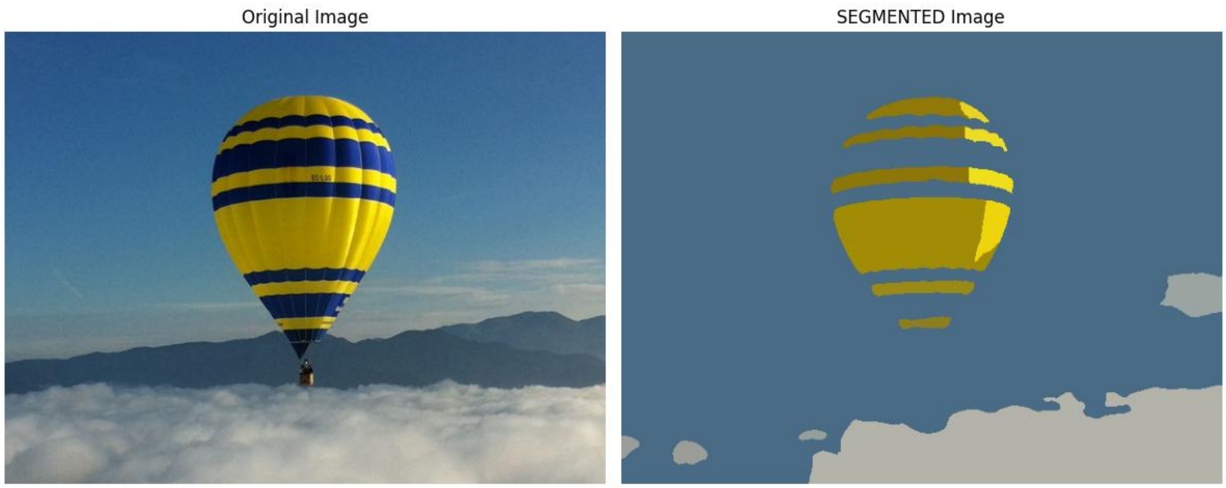
Segmentation on **image1.pgm** was performed using a spatial bandwidth of hs = 10, a range bandwidth of hr = 24, and a minimum region size of M = 160. The algorithm successfully partitioned the image into coherent regions corresponding to meaningful facial components such as the nose, cheeks, eyes and surrounding fur. Small noisy regions were effectively eliminated through region merging, resulting in a cleaner and more interpretable segmentation. While some subtle intensity variations were merged into large regions, this behavior is expected for reducing over-segmentation. Overall, the results demonstrate that Mean Shift segmentation is capable of producing clear and meaningful partitions while preserving essential image structures.

Grayscale Image (image3.pgm) :



This image is another example of grayscale segmentation.

Color Image (image7.ppm) :



The color segmentation case, the algorithm grouped pixels into regions based on both spatial proximity and color similarity. Distinct color areas were separated, and small fragmented regions were successfully merged, producing visually consistent segments. The results confirm that the Mean Shift algorithm performs well for unsupervised segmentation in both grayscale and color images.

4.3. Performance Observation

A notable limitation of the mean shift implementation is its high computational cost. Since Mean Shift operates iteratively on each pixel and evaluates neighboring pixels within the bandwidth range, the processing time increases significantly with image size. As a result, the program requires several minutes to process an image, making it more suitable for small to medium resolution inputs unless further optimization is applied.

5. Conclusion

In this project we successfully implemented the Mean Shift algorithm for both image filtering (smoothing) and image segmentation. The program supports both grayscale and color images, preserves edges during smoothing, and produces coherent segmented regions while eliminating small noisy areas. Experimental results confirm the effectiveness of Mean Shift as an unsupervised image analysis technique. However the iterative nature of the algorithm results in relatively long processing times, especially for large images. Despite this limitation, the project demonstrates the practical value of classical computer vision methods and provides a strong foundation for future improvements such as performance optimization and faster neighborhood search strategies.