OPTIMIZATION METHODOLOGY FOR DENOISING IMPLEMENTATION IN HIGH PASS FILTERING OPERATION IN IMAGE PROCESSING

An Algorithm Based on Iterative Optimization to Achieve High Pass Filtering with Denoising Capability

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HIGH PASS FILTERING

- Low-frequency components represent the smooth or slowly varying regions, such as background or large-scale structures, while high-frequency components correspond to the fine details and edges in an image.


Figure 1.1 : Original Picture


Figure 1.2 : Gaussian High Pass

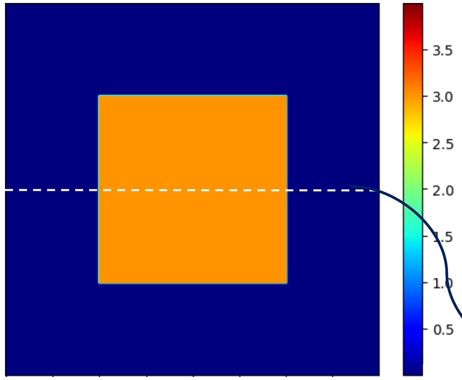
Figure 2.1 : Rect Object

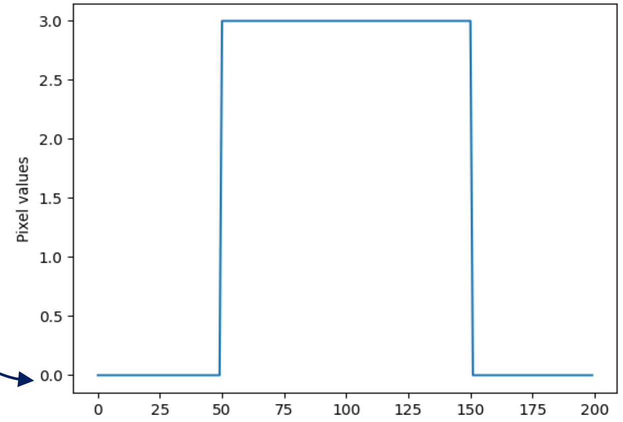

Figure 2.2 : 100th line of rect object

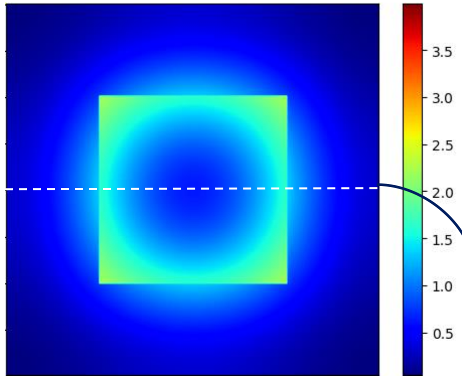
Figure 3.1 : High Pass

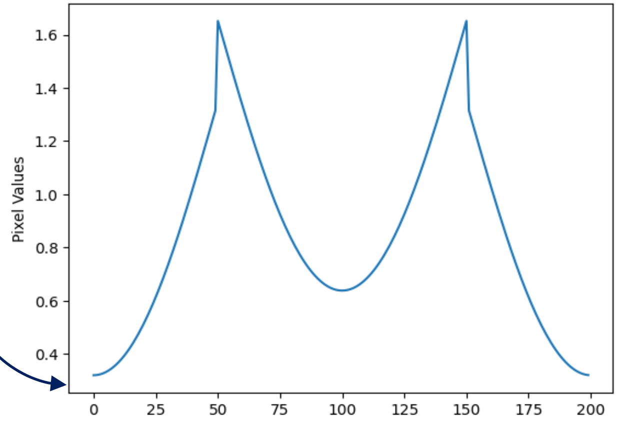

Figure 3.2 : 100th line of filtered rect object

NOISE (THE UNWANTED HIGH FREQUENCY COMPONENT)

Figure 4 : Image with noise

- Noise in an image is the presence of artifacts such as random variation of brightness or color information, that do not originate from the original scene content

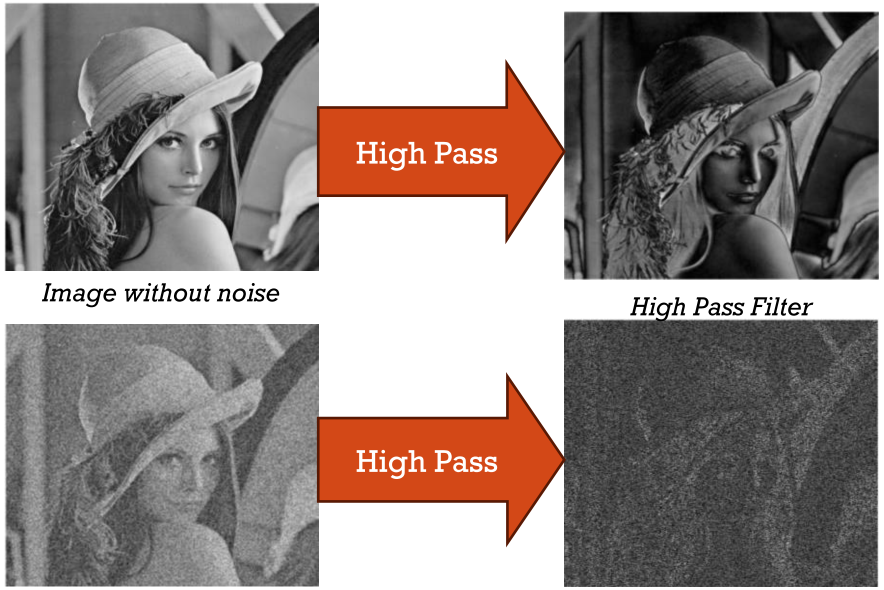

Image without noise

High Pass Filter

Image with noise

Hindered edges appear because of noise

Figure 5 : Effect of noise on High Pass Filtering

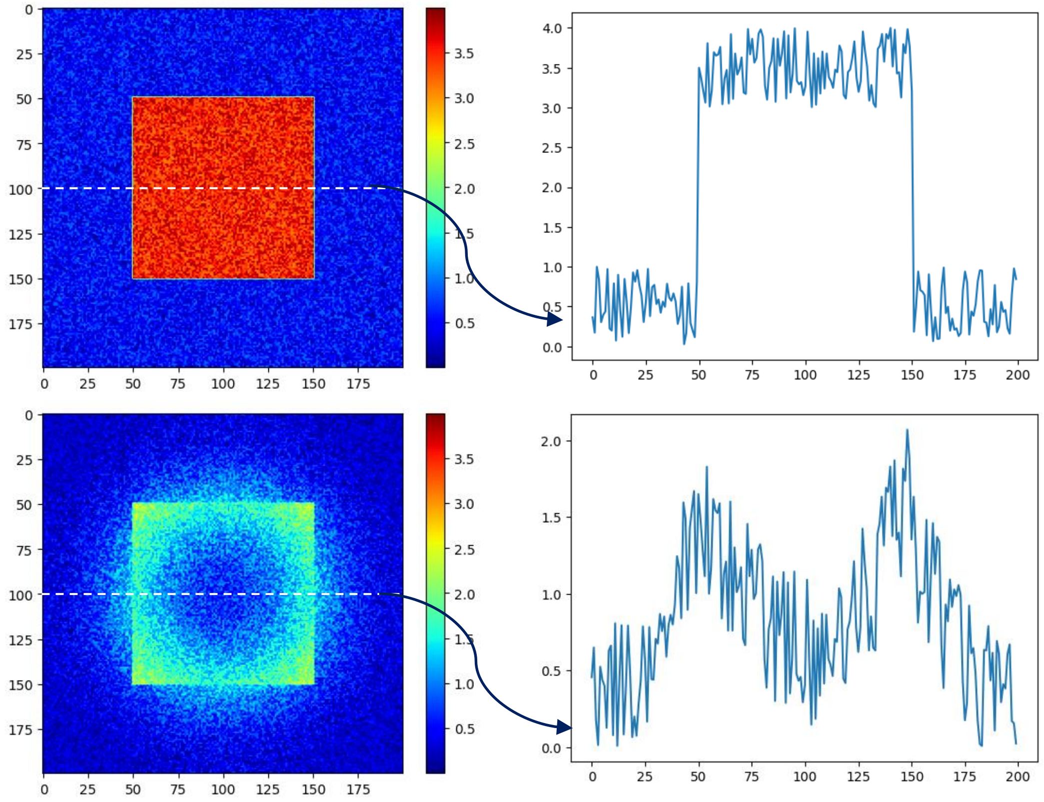

Figure 6 : Effect of noise on High Pass Filtering of Rect Object

TOTAL VARIATION (T.V.)

- Total variation (TV) is a concept used in image processing and computer vision to measure the amount of variation or change in intensity within an image. It quantifies the overall "smoothness" or "regularity" of an image by considering the differences between neighbouring pixels.

- The Total Variation is calculated by summing up the absolute differences between adjacent pixel values in both the horizontal and vertical directions.

0	0	0	1	1	1
0	0	0	1	1	1
0	0	0	1	1	1
0	0	0	1	1	1
0	0	0	1	1	1
0	0	0	1	1	1

Matrix A

Gradients

0	0	0.5	0.5	0	0
0	0	0.5	0.5	0	0
0	0	0.5	0.5	0	0
0	0	0.5	0.5	0	0
0	0	0.5	0.5	0	0
0	0	0.5	0.5	0	0

$A_x = \; Gradient\ along\ x - axis$

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

$A_y = \; Gradient\ across\ y - axis$

$$\mathrm{TV(A)} = \sum |\nabla \mathrm{A(X,\ Y)}| = \sum \sqrt{|A_x|^2 + \left|A_y\right|^2} = 6$$

TV DENOISING

- Intuitively, the total variation measures the amount of variation or "edginess" in an image. Images with high total variation tend to have sharp edges, strong contrasts, and a lot of details. On the other hand, images with low total variation appear smoother and less detailed.

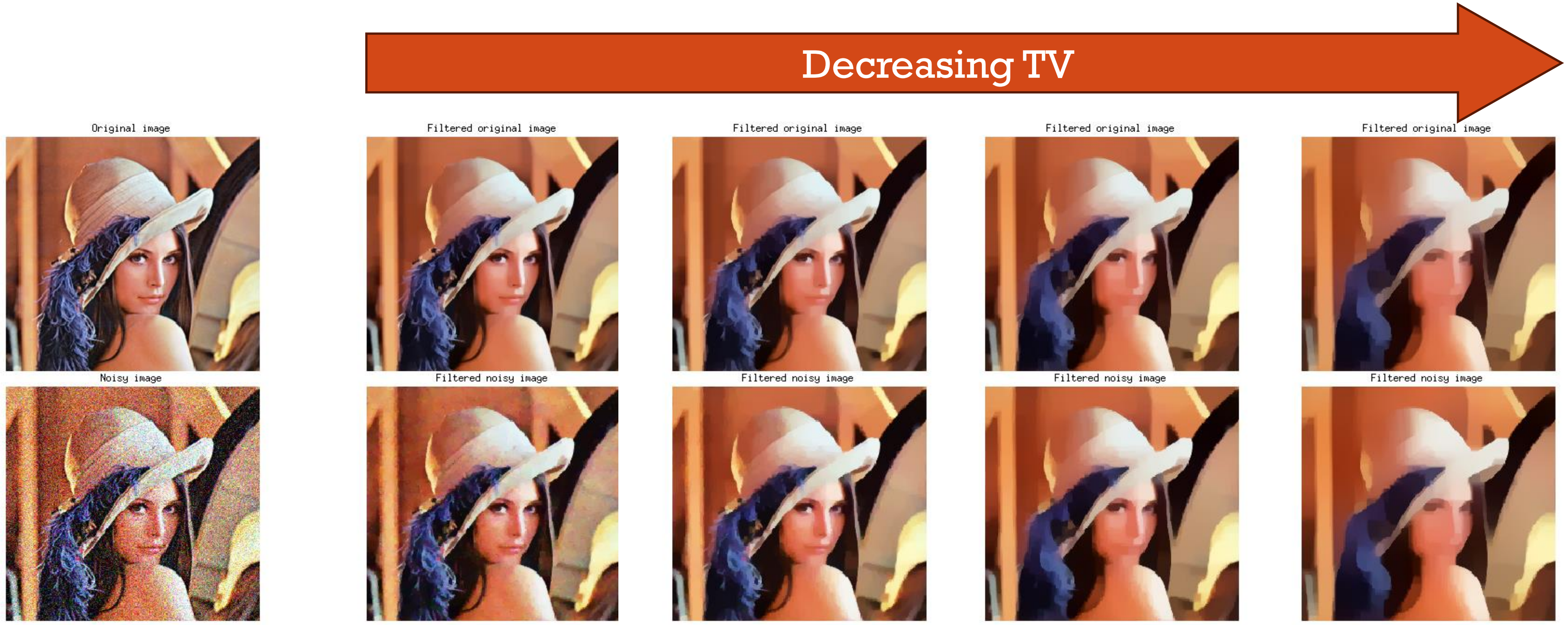

Figure 7 : TV Denoising

ITERATIVE OPTIMIZATION

- Optimization refers to the process of maximizing or minimizing some objective function relative to some constraints.
- Objective : High Pass Filtering
- Constraint : Noise Reduction

- In iterative optimization Key Steps are -
  1. Initialization of solution
  2. Evaluation using an objective function
  3. Update towards the optimal solution
  4. Convergence Check
  5. Termination or Refinement

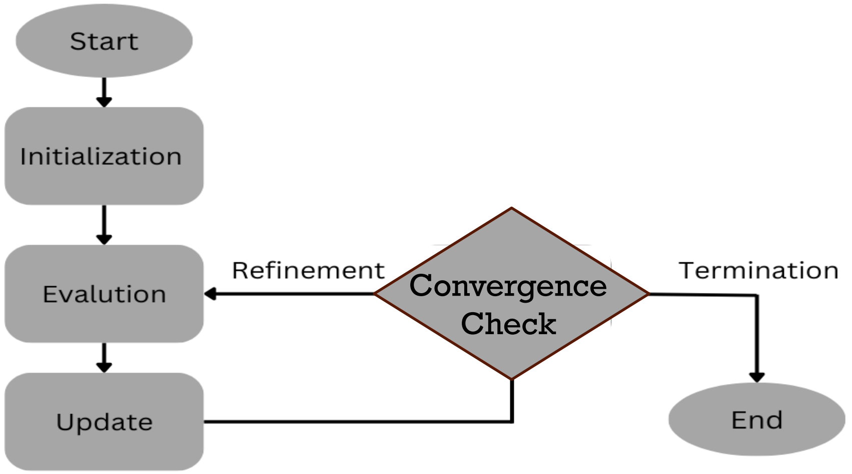

Figure 8 : Flow chart of iterative optimization

APPROACH TO ALGORITHM : EVALUATION & UPDATE

Evaluation : Objective Function

- Objective Function :

$$\min C = ||g_{out} - \hat{A}\, g_{in}||^2 + \alpha\, TV(g_{in})$$

- Where
  - g_{out} → Recorded noisy image after applying high pass filter.
  - $\hat{A}$ → High Pass Filter model
  - g_{in} → Guess solution.
  - α → weight assigned to the Total variance.
- $C_1 = ||g_{out} - \hat{A}\, g_{in}||^2$ is similarity parameter.
- $C_2 = TV(g_{in})$ is the total variation in the solution image.

Update : Gradient Descent Method

- We calculate gradient of function at given point and take repeated steps in the opposite direction of the gradient. The function should be convex and differentiable.
- Update: $g_{in} = g_{in} - t\, \nabla C$; t = step size

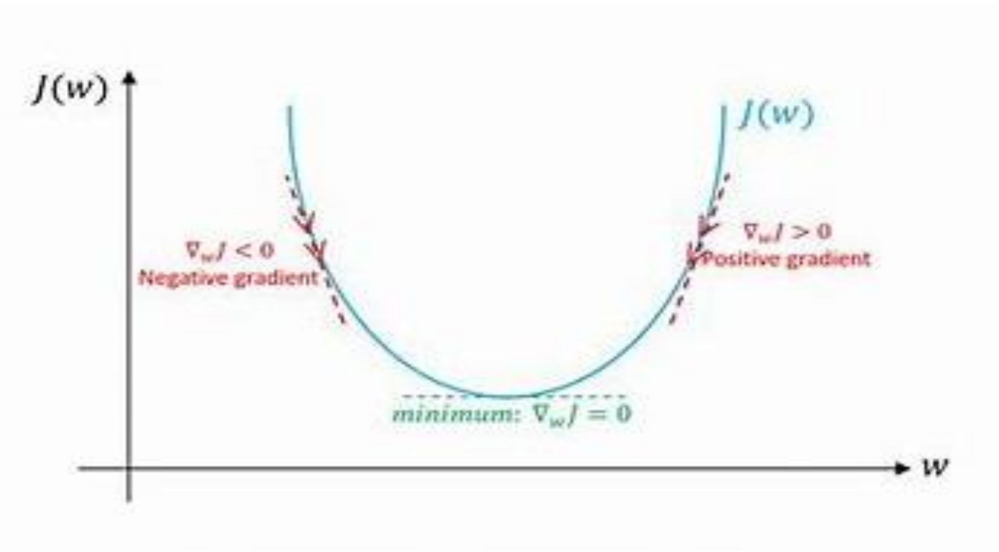

Figure 9 : Gradient Descent Method

RESULTS (1)

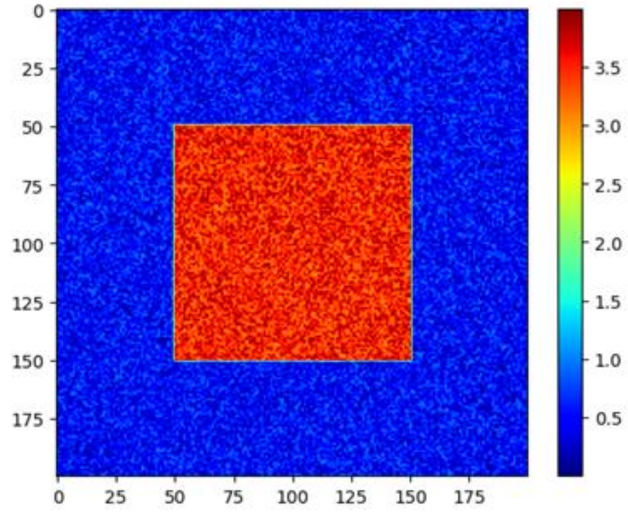

Figure 10.1 : Rect with noise

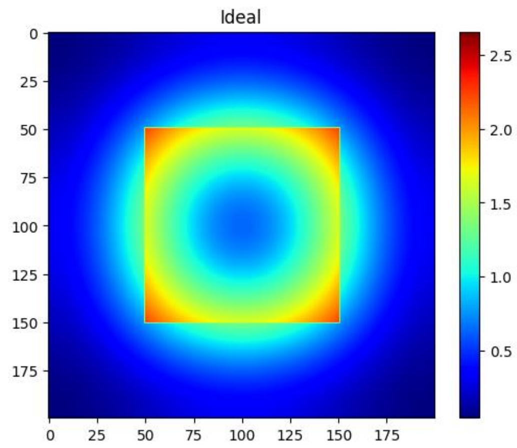

Figure 10.2 : Ideal High Pass

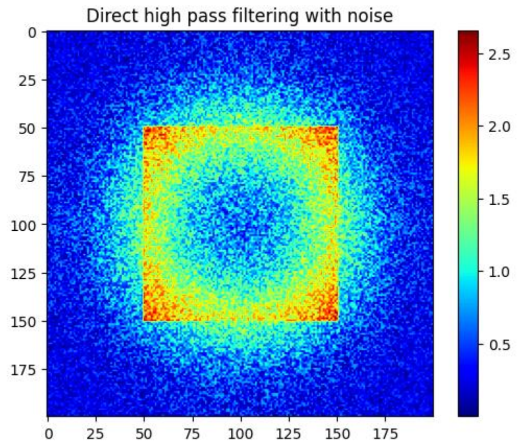

Figure 10.3 : Actual High Pass

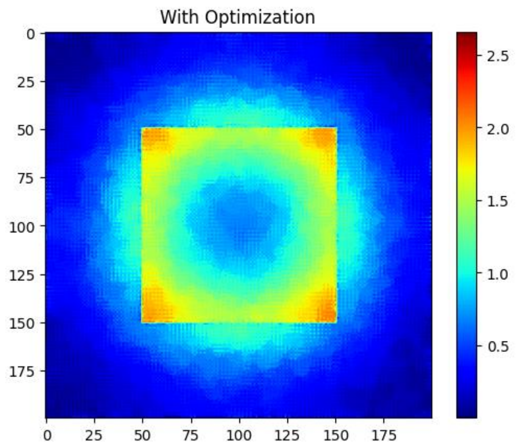

Figure 10.4 : Optimized filtering

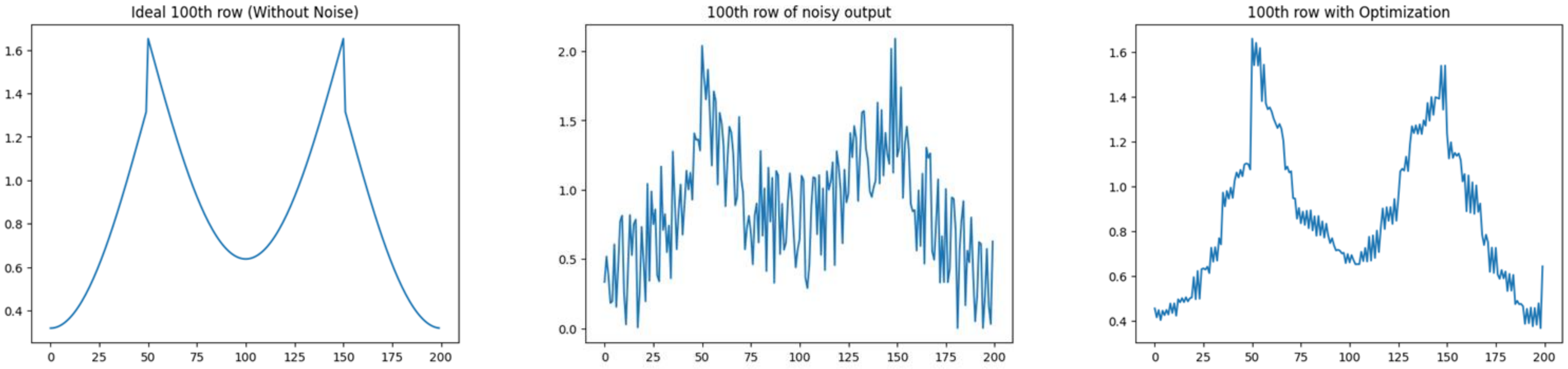

Figure 10.5 : 100th row of each output

COMPARING WITH OTHER DENOISING METHODS

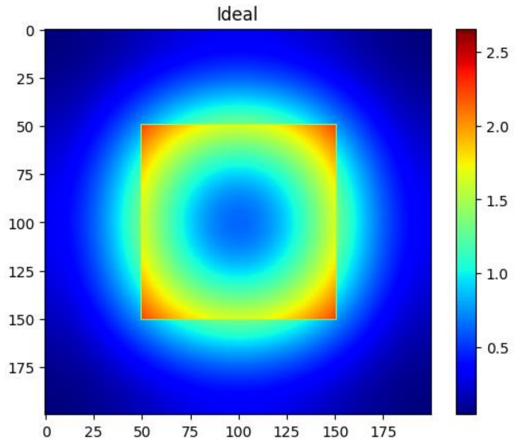

Figure 11.1 : Ideal output

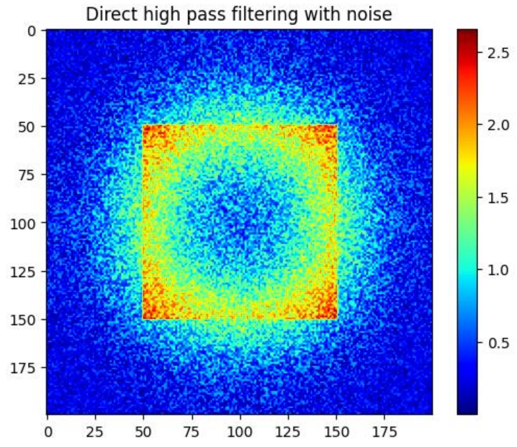

Figure 11.2 : Recorded output

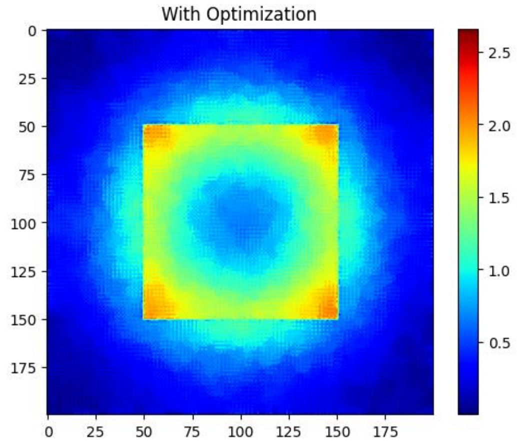

Figure 11.3 : Optimized output

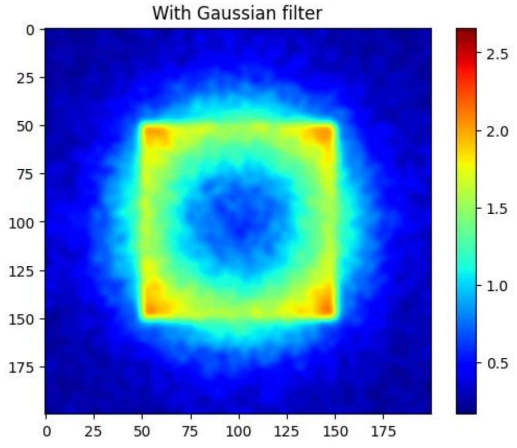

Figure 11.4 : Gaussian filter

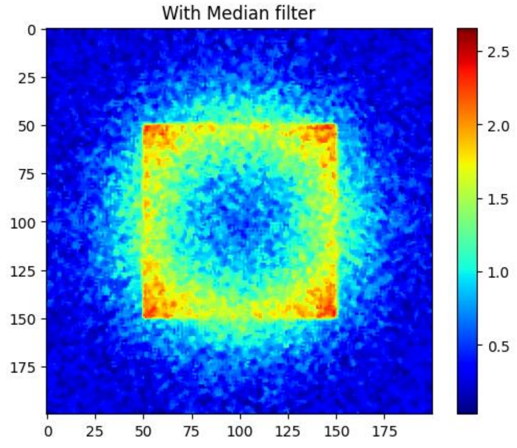

Figure 11.5 : Median Filter

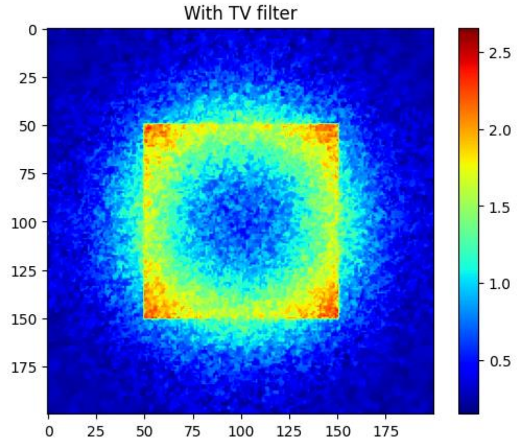

Figure 11.6 : TV Filter

COMPARING

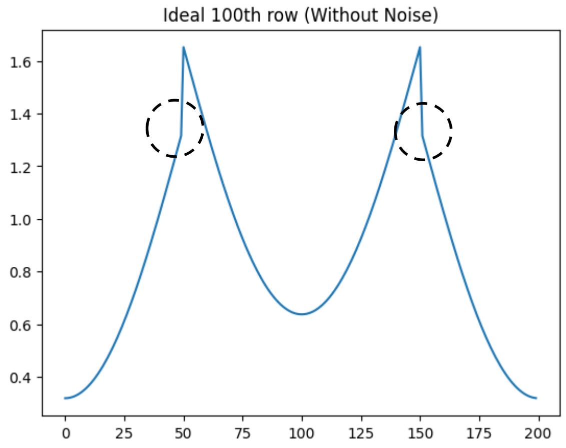

Figure 12.1 : Ideal output

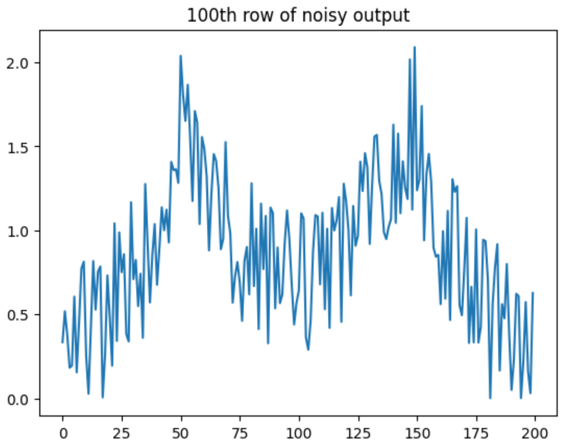

Figure 12.2 : Recorded output

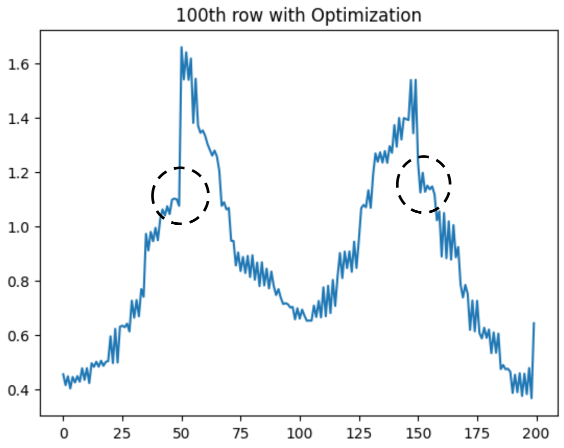

Figure 12.3 : Optimized output

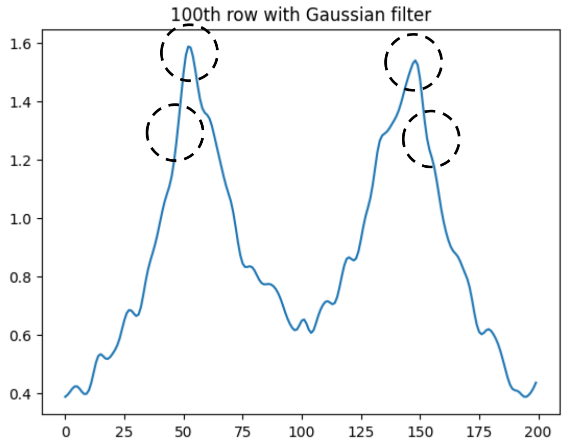

Figure 12.4 : Gaussian filter

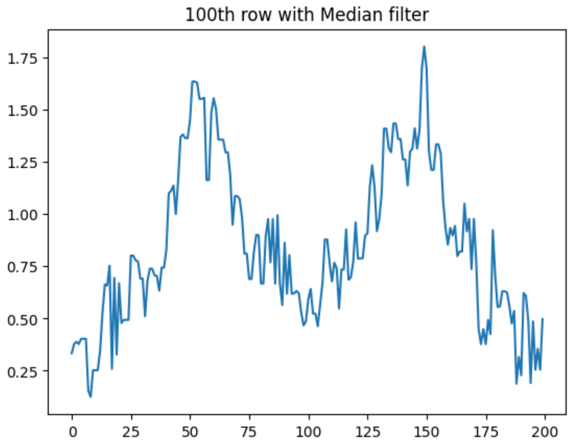

Figure 12.5 : Median Filter

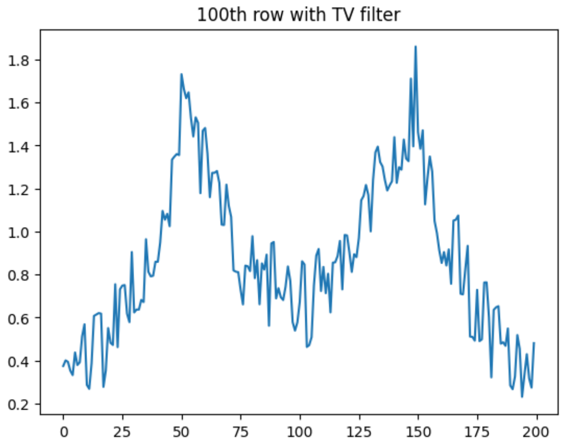

Figure 12.6 : TV Filter

RESULTS (2)

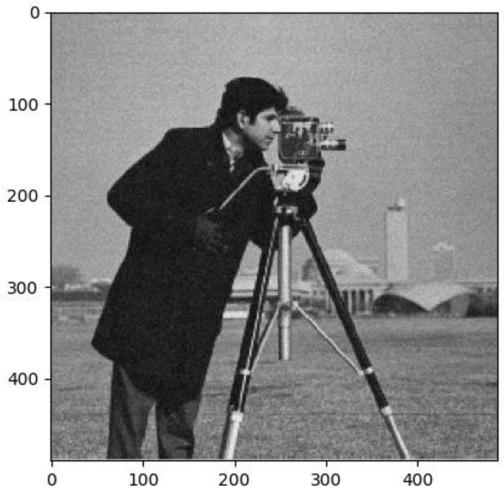

Figure 13 : Cameraman Image

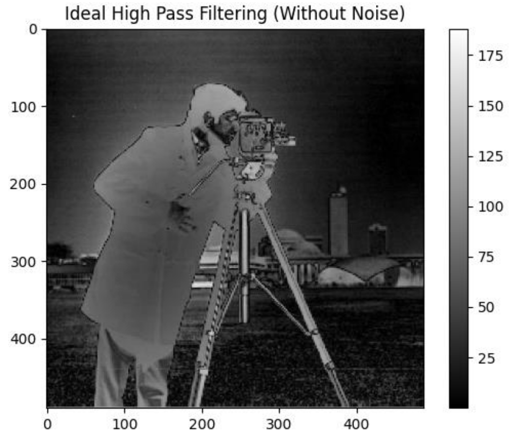

Figure 13.1 : Ideal output

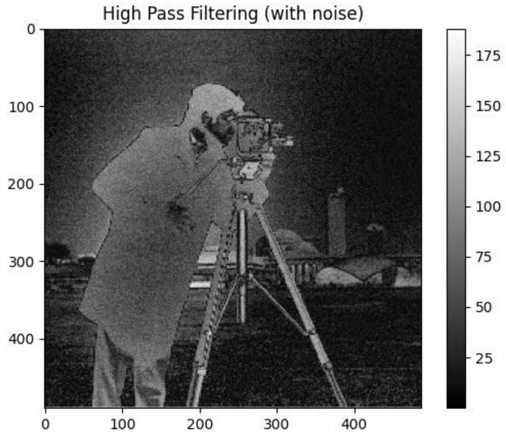

Figure 13.2 : Recorded output

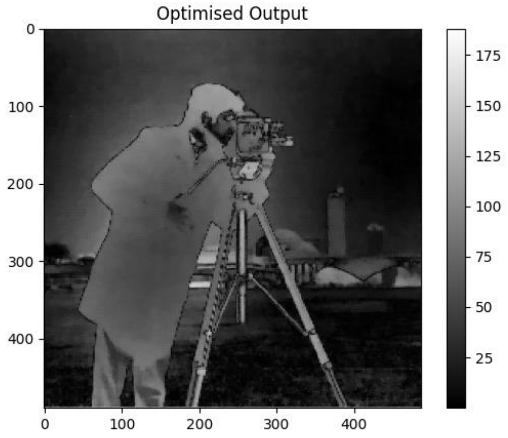

Figure 13.3 : Optimized output

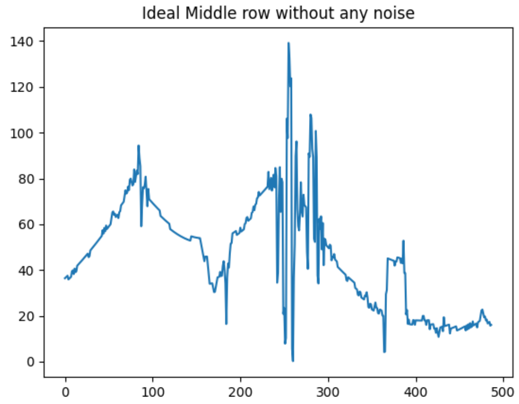

Figure 13.4 : Ideal output

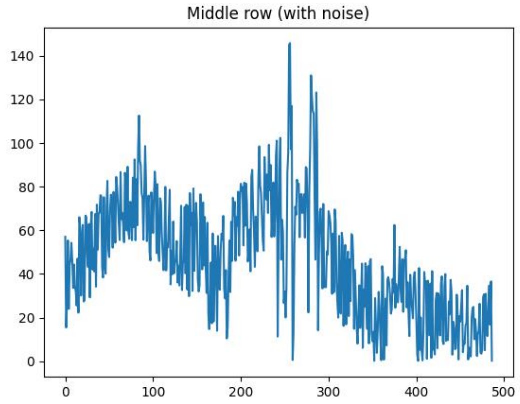

Figure 13.5 : Recorded output

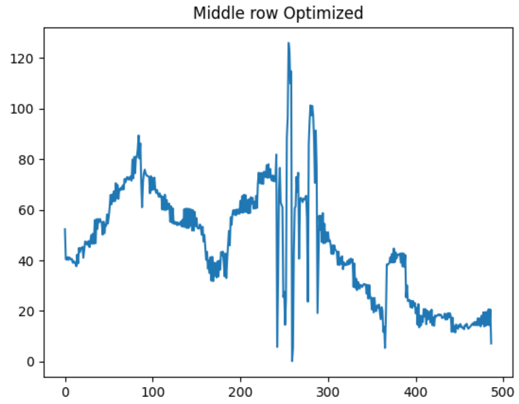

Figure 13.6 : Optimized output

REFERENCES

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Thank You