EXPLORATORY PROJECT

2023 Odd sem

Topic : Image Denoising using Spatial Filters

IMAGE DENOISING

Image denoising is like cleaning up a blurry or speckled picture to make it more transparent. Photos can get messy for different reasons, like camera issues or transmission glitches. Denoising techniques are special tools that help remove this mess and improve the picture quality. There are different type of filters used to denoise the images. This report explores some of these tools in Spatial Domain. The goal is to help choose the right tool to make pictures look better.

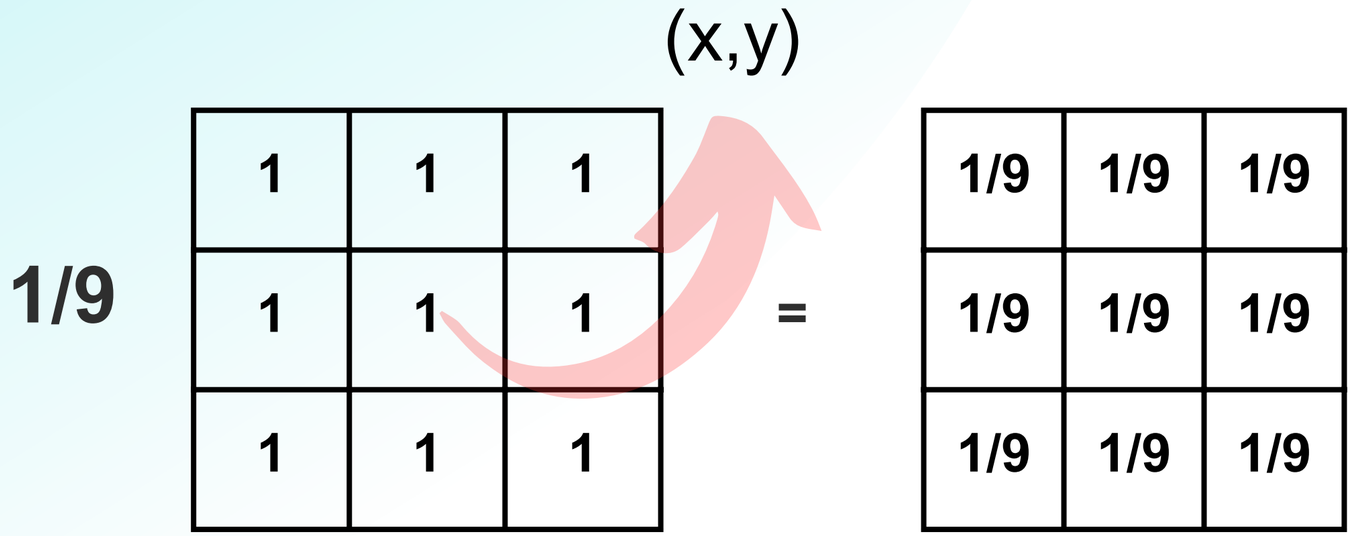
DIFFERENT TYPES OF SPATIAL FILTERS

- Linear Filters
  - Mean Filter
  - Median Filter
- Non - Linear Filters
  - Gaussian Filter

MEAN FILTER/ BOX FILTER

It is a common type of spatial filtering that replaces the value of each image pixel with the average value of its neighboring pixels.
It is also called an Averaging Filter.

MASK OF MEAN FILTER



- We apply this mask to every image pixel, and we replace the present pixel intensity value with the newly obtained pixel intensity value.
- Here, applying mask means to multiply the every element of mask matrix with corresponding pixel.

MORE DETAILS ABOUT MEAN FILTER

- It is computationally simple.
- It is typically used for General Noise Reduction.

Pros:

- It is effective in reducing the salt and pepper noise or random noise. (By using the concept of Spatial Averaging)
- It is used to eliminate the high-frequency components of the image, making the image Smoother. (Spatial Averaging)

Cons:

- Causes Blurring of Image.

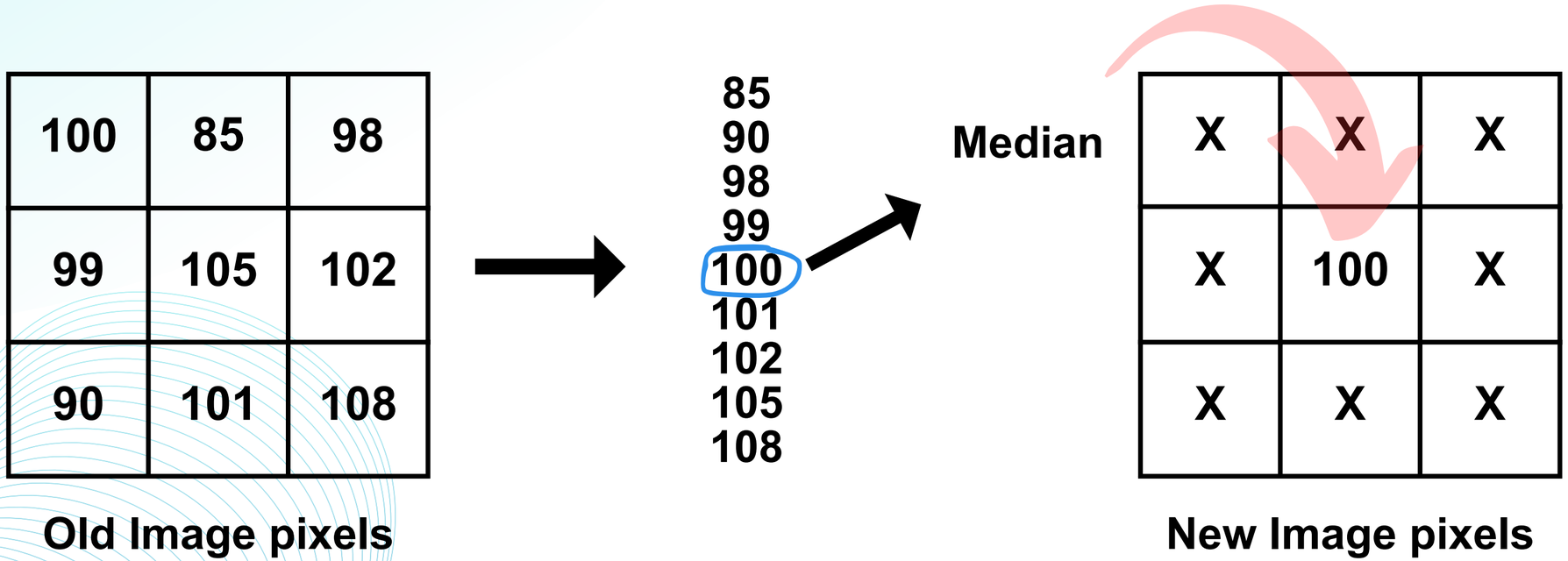
MEDIAN FILTER

This is one of the non-linear spatial filters for processing the denoising operation for the image with noise.

It replaces the old pixel intensity of the pixel (x,y) with the median of the collection of all the neighbouring pixel intensities.

MASK FOR MEDIAN FILTER

For example, if the image has a pixel neighbourhood like the one below, the median value will be selected from this collection as the new intensity for the pixel(x,y)



MORE ABOUT MEDIAN FILTER

- It is Computationally Simple.
- Majorly used for processing the Salt and Pepper Noise.

Pros

- Robust against outliers and extreme values.
- Effective in preserving edges and fine details comparable with mean filter.

Cons

- It can make the image slightly smoother.
- Slower processing compared to Mean filter as the computation cost is increased.

GAUSSIAN FILTER

- This type of Linear Filter helps in the processing of the Gaussian Noise.
- It is based on Gaussian Distribution Function. (which is also called as Normal Distribution)

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

- It operates by the application of Convolution of image with Gaussian Kernel, which is a matric of values determined by Gaussian Distribution/Normal Distribution.

MASK FOR GAUSSIAN FILTER

$$\frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

- The filter emphasises central pixels and gradually reduces weights for pixels farther from the center, following the Gaussian distribution.
- It convolutes with the image pixels to get the filtered image.

MORE ABOUT THE GAUSSIAN FILTER

- This filter is Computationally more expensive.
- This Filter is mainly used to process the Gaussian Noise.
- The choice of sigma influences trade-off between noise reduction and preservation of image.

Pros:

- The gradual fall off of weigths produces the smoother result compared to other filters
- Customisable: The standard deviation of the Gaussian function allows control over degree of Smoothing.

Cons:

- Computationally more expensive.
- Edge blurring

COMPARATIVE STUDY

Filters \ Metrics	PSNR Peak Signal- to-Noise Ratio	SSIM Structural Similarity Index
Gaussian Filter (3x3 Filter)	**15.3980**	**0.2163**
Mean Filter	**17.5002**	**0.3808**
Gaussian Filter (5x5 Filter)	**20.8239**	**0.5654**
Median Filter	**21.8362**	**0.6388**

METRICS USED

Peak Signal - to - Noise Ratio (PSNR)

- **Peak Signal to Noise Ratio (PSNR) is a metric used to evaluate the quality of an image or a signal, typically after it has gone some form of processing. It is the measure of the ratio between the maximum possible power of the noise(Original Image) and the power of the noise.**

Formula:

$$PSNR = 10 \cdot \log_{10}\left(\frac{\text{MAX}^2}{\text{MSE}}\right)$$

MAX- Maximum pixel value of the image\

MSE-Mean Square error(Avg of squared differences between the original and processed image

Structural Similarity Index (SSIM

- **Structural Similarity Index (SSIM) is a metric that quantifies the similarity between two images.**
- **It is computed using 3 components: Luminance(Brightness), Contrast, Structure.**

Formula:

$$\text{SSIM}(X,Y) = \frac{(2\mu_X\mu_Y + C_1)(2\sigma_{XY} + C_2)}{(\mu_X^2 + \mu_Y^2 + C_1)(\sigma_X^2 + \sigma_Y^2 + C_2)}$$

- **Ux and Uy are the average luminance of images X and Y.**
- **sigma^2(x) and sigma^2(y) is variances of luminances of X and Y.**
- **sigma(xy) is covariance of the luminance values in images X and Y.**
- **C1 and C2 are constants to avoid instabilities when denominators are tending to 0. C1=(k1*L)^2 , C2= (k2*L)^2 (where L is the dynamic range of pixels and k1 & k2 are constants**

FILTERED IMAGES

Original Image

Salt and Pepper Noisy Image

Mean Filter Applied Image

Original Image

Guassian Noisy Image

Gaussian Filter Applied Image

My Original Image

Noisy Image

Median Filtered Image

Assigned Teacher

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Mnc Part 2

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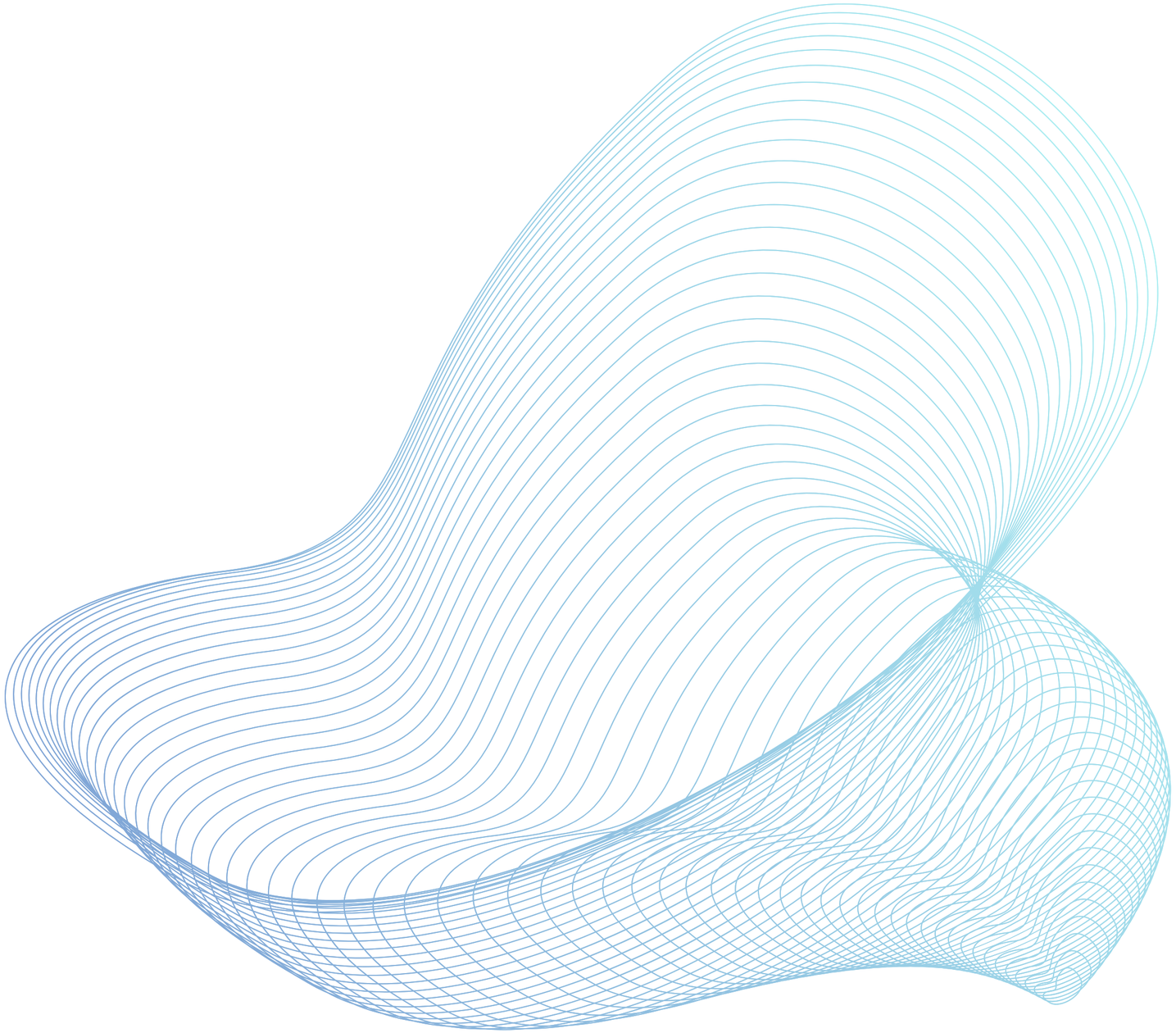

THANK YOU