Module 4: Critical Thinking

Option #1: Mean, Median and Gaussian Filters

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**Image Filtering**

In the field of image processing, filters are commonly applied to remove noise and enhance image quality. The three types of filters explored in this exercise were mean, median, and Gaussian. In which case, each has their unique characteristics and applications. This summary focuses on how well these filters perform for noise removal, preservation of image features, and which method yields the best results visually.

Impulse noise, often referred to as "salt and pepper" noise, consists of randomly scattered bright and dark pixels. It can be problematic in digital images as it disrupts the smoothness and clarity of the image. Among the filters tested, the median filter is generally preferred for removing impulse noise. This is because the median filter works by replacing each pixel with the median value from the surrounding neighborhood, which effectively eliminates noise while preserving edges and fine details better than other filters (Gonzalez & Woods, 2018). In contrast, the mean filter averages pixel values, which can blur edges and features, making it less effective for impulse noise removal. The Gaussian filter, though also effective for noise reduction, can lead to some blurring of edges, especially when the sigma value is too high.

The visual performance of the filters was analyzed by comparing their effects across different kernel sizes: 3x3, 5x5, and 7x7. Additionally, two different sigma values (0.8 and 2.0) were used with the Gaussian filter to observe the impact of sigma on the filter’s effectiveness.

The mean filter, applied with various kernel sizes, blurred the image uniformly by averaging neighboring pixels. While this filter was effective in reducing some types of noise, it caused noticeable blurring of the image. Features such as edges and fine details were lost as the kernel size increased. For example, using a 7x7 kernel led to significant blurring of text and smaller image features. This blurring effect can be detrimental if detail preservation is critical.

The median filter, particularly effective at removing impulse noise, also showed good results with different kernel sizes. The 3x3 median filter provided a good balance between noise reduction and feature preservation. As the kernel size increased, the image became smoother, but edge preservation was notably better than with the mean filter. However, larger kernel sizes still led to some loss of fine details.

The Gaussian filter, applied with two sigma values (0.8 and 2.0), showed interesting results. The sigma value of 0.8 provided a mild blur that effectively reduced high-frequency noise while retaining more details compared to the larger sigma value of 2.0. With sigma 2.0, the blur became more noticeable, but the filter was still effective at smoothing out the noise. The 5x5 and 7x7 kernels provided the best results with the Gaussian filter as they helped spread the effect of the Gaussian kernel more evenly across the image.

Visually, the Gaussian filter with a 5x5 kernel and sigma 0.8 performed the best. It provided a good trade-off between noise reduction and feature preservation. The sharper edges and more detailed structures were better maintained compared to the mean filter, while also smoothing out unwanted high-frequency noise. This result was particularly notable in images with small text and detailed textures, where the Gaussian filter maintained clarity better than the other filters.

Preservation of image features is essential, especially in applications where fine details, textures, and sharp edges are critical. For example, in medical imaging or satellite imagery, the ability to distinguish small features is crucial. In such scenarios, filters like the Gaussian filter with smaller kernel sizes are preferred as they balance noise reduction with feature preservation. The loss of fine details in a heavily blurred image could lead to misinterpretation, making feature preservation a crucial factor in choosing the appropriate filter.

The results align with the preferred method of noise reduction and feature preservation. The median filter worked well for impulse noise, confirming its effectiveness for this specific type of noise. However, the Gaussian filter, especially with smaller kernels and a moderate sigma value, proved to be the most versatile filter in terms of balancing noise reduction and feature preservation. This is consistent with common practices in image processing, where Gaussian filtering is often preferred for general noise removal due to its ability to maintain smoother transitions and details without causing too much distortion (Derrick & Wilson, 2016).

In conclusion, while the median filter is preferred for impulse noise removal, the Gaussian filter provides the best overall performance for general noise reduction and feature preservation. The results confirm that kernel size and sigma play a crucial role in balancing these two aspects. The findings are consistent with established image processing practices, where the choice of filter depends on the specific type of noise and the importance of preserving image details.

**References**

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Jiang, J., & Zhang, J. (2014). A study on impulse noise removal using a median filter. Signal Processing, 101, 242-254. https://doi.org/10.1016/j.sigpro.2013.09.017