Module 4: Critical Thinking

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Mean, Median, and Gaussian Filters

Image filtering is a critical preprocessing step in enhancing image quality and removing noise from the image. In this exercise, we will evaluate the mean filter, median filter, and Gaussian filter and observe how they perform when applied to an image with impulse noise. In each of the three cases, we will examine how each of the filters performs in 3x3, 5x5, and 7x7 kernel sizes. While a mean filter will smooth the image, it will also blur the edges and keep some noise intact. The median filter performs better with impulse noise, as it removes outliers while retaining the pictures edges. The Gaussian filter is an intermediary, and retains detail while smoothing, in which the sigma values operates, determine the level of smoothness. For example, if we are exploring two sigma values such as .5 or 2.0, we can stepwise see how they increase the level of blur.

Best for Removal of Impulse Noise

The median filter is the best choice for eliminating impulse noise. This because it changes current pixel with the median value of the surrounding neighborhood as opposed to the average value (Jayanetti, P., 2020, October 16). This is a key distinction as it defines the inherent property of the median filter—the ability to reject outliers. Impulse noise is characterized by extreme high or low pixel values that appear intermittently, and since the median is negative to each extreme value, it can select the middle value from the neighborhood organized by intensity, decreasing the effect of impulse noise.

Another advantage of the median filter is it's edge preservation capabilities (Fisher, R., et al, 2003) . Compared to the mean or Gaussian filter, which will approximate the true edge by blurring the sharp transition, the median filter holds to true edge value. Edge valued pixels usually occur in intensity clusters, which leads to edge being accurately reflected, even after applying the median replacement process.

The median filter is non-linear, contrasting to the mean and Gaussian which are linear in nature. The smoothing effects of a linear filter tend to homogenize the noise, which when observed, reduces their visibility, but does not remove them. The result is that the non-linear median filter can reject isolated noise points entirely, with no creation of other intermediate or average values that diminish the quality of the image.

Best Visual Filter

According to the applied filters and their visual results in our comparisons, the median filter with a 5×5 kernel size generally gives the best overall result in usual image processing problems. The 5×5 kernel size balances the reduction of noise and retention of relevant image data. On the other hand, a 3×3 median filter may leave some residual noise in the image, whereas the 7×7 median filter abrades too much detail and smooths out finer detail too much.

In the case of the Gaussian filter, the 5×5 kernel with the value of sigma as 0.5 looks best. It reduces noise while retaining some structure, partially due to the smaller value of sigma leading to less total smoothing overall. The value of sigma allows for reasonably smoothing an image without substantial blurriness, which is very important in retaining the clarity of the image where detail or important features are located.

There is always some compromise when choosing the best filter, however. The type of noise present in the image is central to the decision, as is the type of image content, especially if there are small textures or larger uniform areas. Other things to consider is the goal of the images processing, including whether the goal is enhancement, analysis, or compression.

Results

The results align with the suggested method for processing impulse noise. The 5×5 median filter consistently produced the best visual results. This is because it is selected based on mathematical reasoning. It selects the median value from the neighborhood rather than averaging.

From its visual output you can see how different kernel sizes affect the performance. The 3×3 median will take out a great deal of the impulse noise, but it may leave behind some noise, particularly when the area that has a lot of static. Sometimes it is not large enough a neighborhood of valid pixels to mediate that outlier when pixels contain impulses. The 5×5 median seems to strike the best balance of taking out the impulse noise while maintaining the edge value and image details. The 7×7 median tends to over-smooth the image to the point where fine textures and subtle detail become wiped out in more complicated areas.By comparison, both mean and Gaussian filters do not eliminate the impulse noise entirely in a given image. They do not remove the sharp black-and-white specks, but diffuse the noise throughout the image. This has the effect of not removing the noise, but smoothing to a degree and rendering the noise to a less visibly impactful grayish smear.

Conclusion

The median filter with a 5×5 kernel was the most effective technique for eliminating impulse noise while maintaining critical image features. Unlike mean and Gaussian filters, which have a tendency to blur or spread noise, the median filter is the superior filter when retaining detail because of its resistance to outliers and edge preservation. The 5×5 kernel consistently provided the best tradeoff between noise reduction and feature retention compared to other kernel sizes, and was consistent with both theories and visual results.

References

Fisher, R., (2003) *Median Filter.* The University of Edinburgh. https://homepages.inf.ed.ac.uk/rbf/HIPR2/median.htm

Jayanetti, P., (2020, October 16) *Remove Salt and Pepper noise with Median Filtering.* Medium. https://medium.com/analytics-vidhya/remove-salt-and-pepper-noise-with-median-filtering-b739614fe9db