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Lab 1: Convolution, Separable Filters, Sliding Windows

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Introduction:

For this lab, three variations of the smoothing (mean) filter were implemented. Each version of the filter implemented was designed to produce the same resulting image with increasing efficiency.

Filter Variation Comparison:

The first filter that was implemented was a basic 7x7 convolution mean filter. This filter worked by averaging the values in the image over a 7x7 square of pixels. The times from this first variation can be observed below in table 1.

Run Number	Time (ns)
1	42420873
2	38286078
3	46445336
4	46768787
5	44299460
6	43873459
7	45160635
8	41000093
9	41487558
10	45614961
Avg	43535724

Table 1. 7x7 Convolution Mean Filter

The basic 7x7 convolution mean filter produced smoothing results in about 44 milliseconds. These same results were produced much quicker by a separated smoothing filter. This filter reduced the total number of computations by summing both columns and rows separately. Once one direction was summed, the results were stored in a temporary array. This array was then summed in the other direction and averaged. The time results from this separated filter can be observed below in table 2.

Run Number	Time (ns)
1	27698785
2	22523096
3	24320079
4	26578831
5	31939475
6	30133472
7	27425354
8	24969109
9	25450240
10	24982162
Avg	26602060

Table 2. 7x7 Separated Convolution Mean Filter

The separated 7x7 convolution mean filter produced smoothing results in about 27 milliseconds. This took almost half the time of the basic mean filter. This time was improved further by the filter that utilized the sliding window technique. This technique combined a separable filter with a further reduction in computations to produce the most efficient smoothing filter. This variation further reduced the total number of computations by storing the calculated sum from each iteration. This resulted in fewer additions by utilizing previously computed values. The timing results from this third variation can be observed below in table 3.

Run Number	Time (ns)
1	7144857
2	6367501
3	6995183
4	6192248
5	6388854
6	7679576
7	8602511
8	5275579
9	6151082
10	5679488
Avg	6647688

Table 3. 7x7 Sliding Window Convolution Mean Filter

The sliding window variation of the smoothing filter produced results in an average of 6.6 milliseconds. This speed increase was substantial when compared to both previous interpretations of the filter. From the first variation to the last, there was about an 85% increase in filtering speed.

Verification:

To verify that all three filters produced the same image, the diff command was used to compare the binary in each file. Using the diff command, I was able to confirm that the filtered image produced by each one of the three different variations was the exact same. Image 1 below shows a terminal output highlighting the two diff verifications that were performed on the three outputted images. Image 2 below shows the bridge.ppm image after one of the filters was applied.

Image 1. Diff Image Verification

Image 2. Smoothed Bridge.ppm