PRP Assignment 1

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- **Methodology of Non-Local Means:**

I went through the reference paper we received and tried to implement the NL-Means algorithm accordingly. We assign a NL value to each pixel in the image using this algorithm, which is the weighted average of all the pixels in the image.

Instead of considering all pixels, we consider a window of size 21x 21 (big window) centred around the pixel to assign an NL value to that pixel for improving the runtime of the algorithm. We construct a flattened vector of size 7x7 (small_window) centred around each of these pixels and calculate the negative exponent of the norm of these two vectors divided by the square of the filtering parameter h(sigma_h) to assign weight between any two pixels p1 and p2. (According to the equations mentioned in the paper). (We change the value of sigma_h to optimize for MSE.)I used a vectorized technique to locate the neighbourhood of all pixels and do other computations because it reduces the algorithm's time complexity dramatically (It would take several hours to compute the same otherwise).

We pad the image on either side with a constant pad value of 13 (= [21/2]+[7/2]) in order to discover the 21x21 (big window) neighbourhood of each pixel and then 7x7 (small window) of each pixel in that submatrix.

Since we would be considering the weight of all the pixels, we will assign the shifted value to all the pixels at every iteration. The V_{ni} and V_{nj} vectors around both pixels are then obtained, and the Z value is calculated using the sum of the 2nd order norm exponents.

Finally, we calculate the NL value by multiplying the weight by the neighborhood's average pixel value and dividing by the normalising constant Z.

- **Metrics obtained for both denoising methods:**

Best Salt_and_Pepper_h : 10
Best gaussian_h: 9
We optimize MSE by varying both these values on the third Image.

Image no.	Type of Noise	noisy psnr	noisy mse	NL psnr	NL mse	gauss psnr	gauss mse	Diff in MSE	Diff in psnr
1	SnP	17.84825	1067.225	27.98098	103.51	27.65694	111.5286	-8.018575	0.324039
	Gauss	20.27806	609.9218	30.04487	64.35669	30.05549	64.19942	0.15727	-0.01063
2	SnP	18.01021	1028.158	23.04838	322.2868	26.58099	142.8832	179.4035	-3.53261
	Gauss	20.26299	612.0426	25.25038	194.1074	28.35817	94.89941	99.20794	-3.10778
3	SnP	17.96756	1038.304	24.60586	225.1614	23.66079	279.8992	-54.73774	0.945076
	Gauss	20.46886	583.7056	26.67251	139.9037	24.18599	248.0167	-108.113	2.486518
4	SnP	17.56518	1139.1	26.17462	156.8985	25.48347	183.9641	-27.06566	0.691144
	Gauss	20.23267	616.3298	28.29944	96.19152	27.14415	125.5062	-29.31463	1.155282
5	SnP	16.74133	1377.043	27.51184	115.3179	26.55191	143.8433	-28.52542	0.95993
	Gauss	21.9192	417.985	29.51706	72.67321	28.65032	88.72546	-16.05225	0.866739
6	SnP	17.89862	1054.917	22.86965	335.8265	23.29139	304.7486	31.07798	-0.42173
	Gauss	20.44425	587.0228	25.57298	180.2113	24.15723	249.6646	-69.45332	1.41575
7	SnP	16.88348	1332.7	24.36961	237.7491	25.17293	197.6	40.14908	-0.80332
	Gauss	21.31606	480.2574	26.67352	139.8711	26.99763	129.8128	10.05831	-0.3241
8	SnP	16.63482	1411.233	28.24583	97.38625	26.81921	135.2569	-37.87068	1.426619
	Gauss	21.96794	413.3199	30.81473	53.90233	29.20463	78.09403	-24.1917	1.610103
9	SnP	17.65804	1115.005	27.69931	110.4458	26.84283	134.5233	-24.07749	0.856483
	Gauss	20.89743	528.8554	30.0345	64.51049	28.67039	88.31643	-23.80594	1.364112
10	SnP	18.259	970.9128	22.33394	379.9148	25.19502	196.5979	183.3169	-2.86107
	Gauss	20.13133	630.8803	24.39574	236.3231	26.30607	152.2205	84.10265	-1.91033

- **My understanding of sigma_h, small_window and big_window parameters:**

The degree of filtering is determined by the parameter h, which is a filtering parameter. It manages the decay of the exponential function, as well as the decay of weights as a function of distance. As a result, if the h value is too high, image features are lost, and if the h value is too low, the image is not denoised to the needed amount.

We define the small_window and big_window parameters to essentially improve the time complexity of our algorithm as mentioned earlier. Here, we check the similarity of pixels in the small window of size 7x7 in its neighbourhood (in this case) within the bounds of only the big window search space/window (i.e, 21x21 neighbourhood in this case) and not with the entire image. This essentially decreases the space over which we search. This comes at the cost of compromising the algorithm if the window sizes are not appropriate. We can choose the appropriate window size that best fits our algorithm and the images that we have.

- **Comments on Observations about which method proves better for different types of noise:**

Clearly, the NL Means Algorithm performs better since it out-does the Gaussian Filtering in 60% of the images on which the Salt and Pepper Noise was applied and also 60% of the images on which the Gaussian Noise was applied.

Observations:

- We see that PSNR has considerably improved as compared to that of Noisy images after filtering.

- The NL Means algorithm works better than Gaussian filter since the Salt and Pepper noise is highly localised and hence can be removed easily by the target window approach of the NL means algorithm.
- We notice that the NL-Means filter actually tries to identify similar patches around noise and tries to remove them, as compared to the Gaussian filter, which might appear to work well indicated by the metrics at times but is actually only flattening the noise instead of removing it.
- We can thus conclude that the NL-Means filter outperforms the Gaussian filter on Salt and Pepper noise and on gaussian noise. The Gaussian filter is essentially on smoothening the noise instead of removing it.

- **Assumptions made while attempting the assignment:**

We obtained the best Salt_and_Pepper_h and gaussian_h as 10 and 9 respectively to optimize the MSE on the third image and assumed that these were the best salt and pepper and gaussian h values for optimizing MSE for all the remaining images too.

Some References:

- https://classroom.google.com/u/0/c/MzQzMzU5MjM3OTMy/a/Mzc5MzE0MTExNjgx/details
- https://ieeexplore.ieee.org/abstract/document/1467423/
- https://drive.google.com/file/d/1NrUXXQgiPtNyfZhHBtKR_yseadwVQDyH/view?usp=drive_web&authuser=0
- https://drive.google.com/file/d/13tJKX0SeafvHdX-VMcAU783TqbxadXP5/view?usp=drive_web&authuser=0
- https://github.com/varunjain3/NLMeansDenoising