Image Denoising - Homework 2 Report

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In this report, we first give a general comparison between Non-Local Means, BM3D, and Multi-Scale DCT denoising. Since MS DCT was studied more in-depth in the previous report, we will focus on a more detailed analysis of the NLMs algorithm.

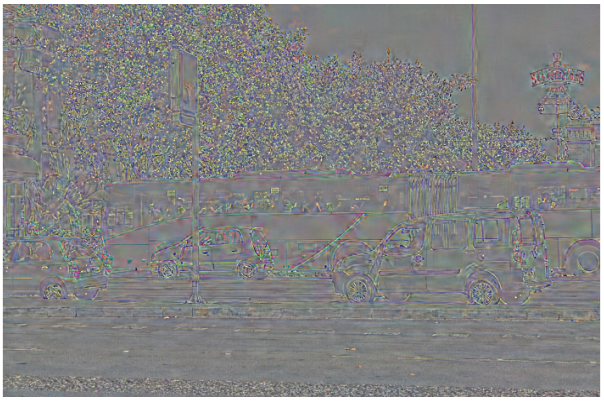
Original

Noisy (19.2247dB)

Non-Local Means (27.69dB)

Difference

BM3D (28.8354dB)



Difference

MS DCT (28.3609dB) Difference

Figure 1: General comparison for noise with σ=30 between Non-Local Means, BM3D, and MS DCT denoising with DCT size = 8, 5 scales, and frec=0.4.

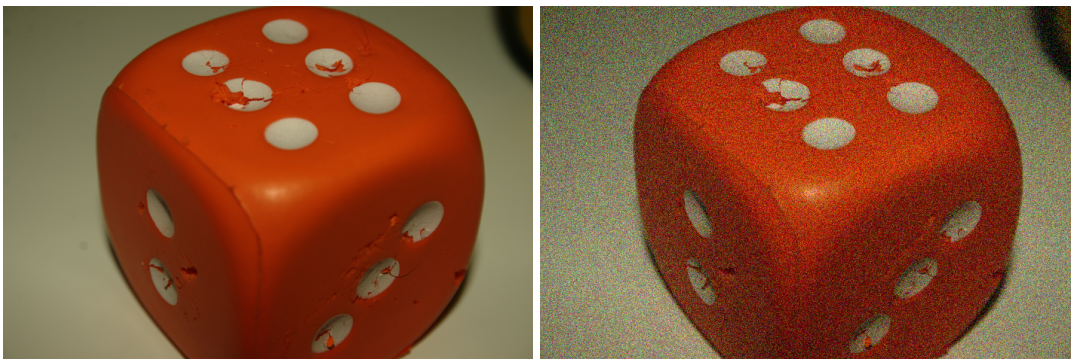
Based on the results of Figure 1 it is clear that the best performing method for the given image, both visually and quantitative (highest PSNR). By looking at the difference between the denoised image and the original, the see that the region where BM3D completely outperforms the other methods is in the details of the red bus and the details of the leaves in the trees. In Figure 2 we take a closer look at that area. We observe that MS DCT introduces artifacts due to ringing effects associated with the thresholding and attenuation of the DCT coefficients. NLM does not have this issue, but the image looks blurry; details of the leaves are lost and instead, we get a much more homogeneous area. Likewise NLM, BM3D does not introduce artifacts but in addition, we obtain much more detail in the leaves. However note that the denoising is not perfect, and there are still several high-frequency information lost.

Original MS DCT

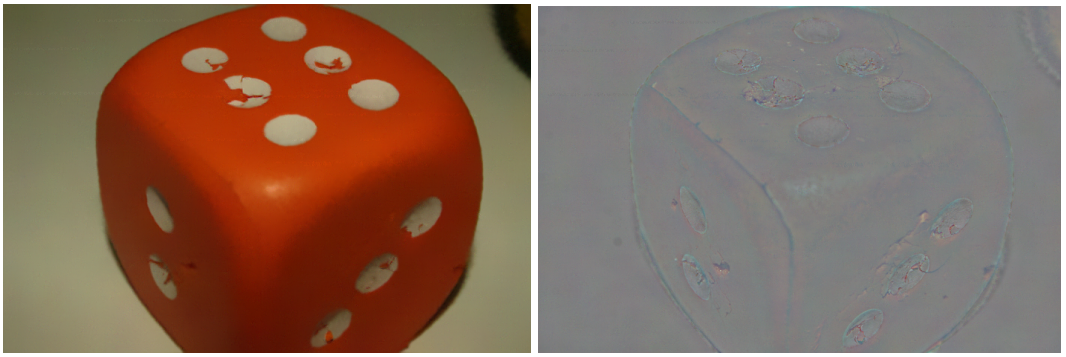
NLM BM3D

Figure 2: Detailed comparison for noise with σ=30 in a region of interest between Non-Local Means, BM3D, and MS DCT denoising with DCT size = 8, 5 scales, and frec=0.4. This is a zoom-in version of Figure 1.

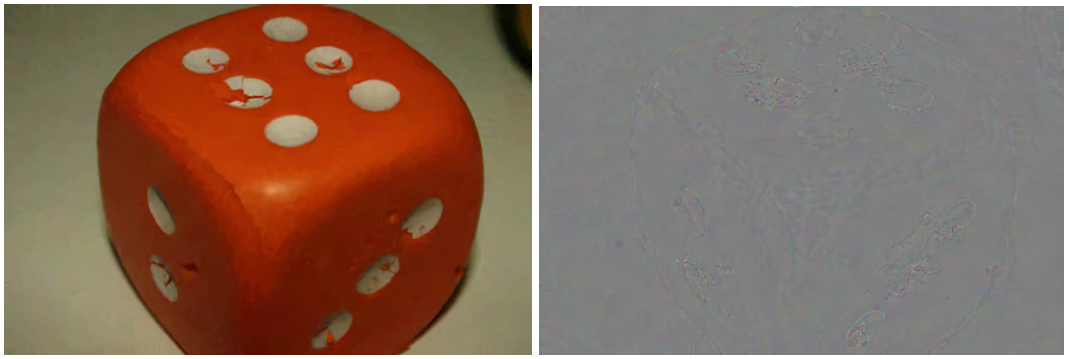
Since NLM is based on averaging similar patches within the image, it may produce some blur and lead to loss of detail (smooth denoised image). In particular, in Figure 3 several details in the dice are lost. However, we do get good denoising in the flat red areas and the edge between the dice and the background is not blurred at all. BM3D does not suffer from an excess smoothness and in fact, more details are preserved, but the results in the flat red areas and background are a bit more oscillating than those of NLM.
Similar problems are found for NLM in Figure 4, where details in the leaves and the petals are lost and the overall denoised image looks too smooth. Results obtained by BM3D are notoriously better; several details in petals and leaves are preserved.



Original Noisy



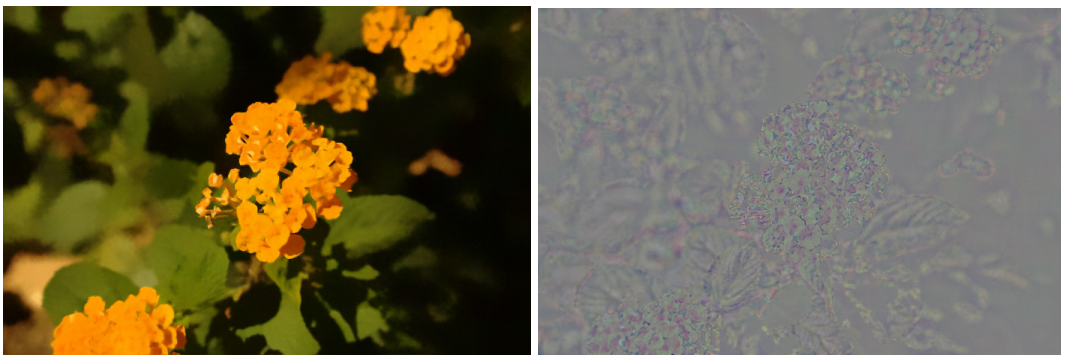
NLM Difference



BM3D Difference

Figure 3: BM3D and NLM results for noise with σ=30.

Original Noisy



NLM Difference

BM3D Difference

Figure 4: BM3D and NLM results for noise with σ=30.

Conclusions

The following is a summary of the most important observations from the previous experiments:

- NLM does not introduce undesired artifacts like those produced by removing frequencies in the transformed domain.
- NLM tends to produce smooth results due to the average of similar patches. This is especially noticeable in small parts of the image. Because of this, a significant amount of detail may be lost but in return flat areas are well denoised.
- Since NLM and BM3D strongly depend on the self-similarity assumption, images with fewer self-similarities achieve poorer results.