Experimental report

Article 1: *Multi-Scale DCT Denoising,* Pierazzo, Nicola and Morel, Jean-Michel and Facciolo, Gabriele

Article 2: *Non-Local Means Denoising*, Buades, Antoni and Coll, Bartomeu and Morel, Jean-Michel

Experiments on the Multi-Scale DCT Denoising

The first article deals with Multi-Scale DCT Denoising. This algorithm is an improvement on the classical DCT denoising algorithm. Indeed, the latter algorithm removes low and high frequency noise using the same method, which can lead to poor results. On the contrary, Multi-scale DCT denoising applies denoising at different patch sizes to limit high and low frequency noise. We will use this algorithm on 3 images: a natural image and 2 more artificial images to highlight its strengths and weaknesses.

Natural image

The first image is a photo that anyone could have taken with his smartphone. We add a standard white noise $\sigma = 30$.

Figure 1: Original image

Figure 3: Noisy image

Figure 2: MS DCT image (PSNR : 30.73dB)

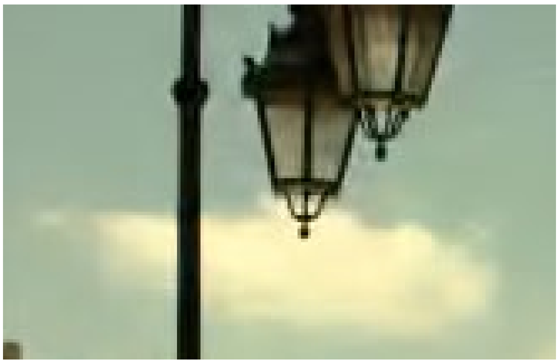

Figure 4: Zoomed in MS DCT image with black oscillations

Contrasted image

The first image is a checkerboard. We add a standard white noise $\sigma = 65$. We keep the hyperparameters as proposed by the article.

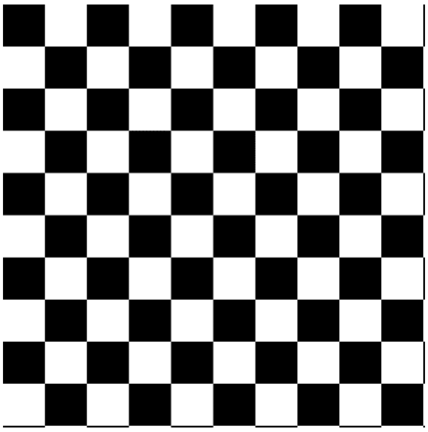

Figure 5: Original image

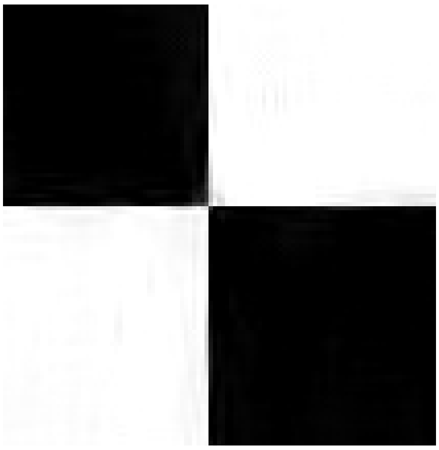

Figure 6: Zoomed in MS DCT image (PSNR: 32.61dB)

Non-repeating image

To compare the MS DCT denoising with the non-local means denoising, it is also interesting to use a non-repeating image: there is no clear repeated pattern. Once again, we add a standard white noise $\sigma = 65$.

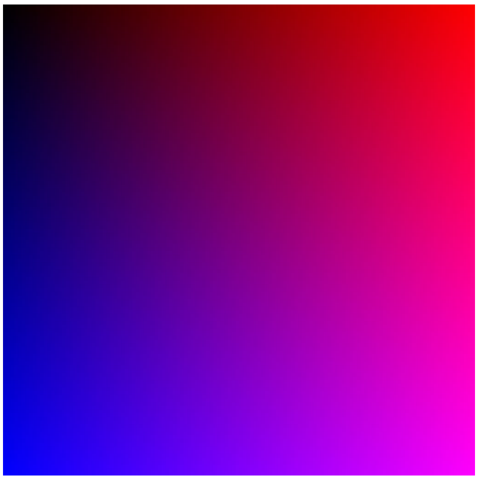

Figure 7: Original image

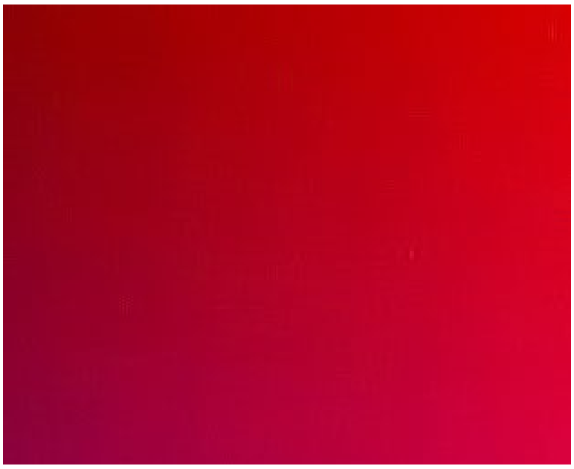

Figure 8: Zoomed in MS DCT image (PSNR: 44.1143dB)

<u>Interpretation of the results:</u>

First, we notice that the algorithm is able to differentiate between high and low frequencies. For example, on the very low frequency gradation image, the multi-scale denoising is 11db better than its single-scale version. The gain is enormous.

On the street image (see Figure 2), the gain in dB is very small compared to the single-scale version but the result shows obvious differences. The PSNR is 0.5dB higher but this is already enough to see improvements on the uniform areas. The multi-scale DCT denoising is very good at smoothing out the homogeneous areas without attenuating the edges. One can thus force a greater homogenisation of the areas by increasing the patch size.

However, using a cosine base to denoise an image easily causes Gibbs oscillations to appear, especially near the black street lamp on a blue-sky background (see Figure 4). These oscillations can be limited by decreasing f_{rec}.

We can also notice that the algorithm brings out spots of greater or lesser intensity. Thus, on the checkerboard, these black spots are rather well seen in the white areas, while on the gradation image, they are seen in the light areas such as the red zone. To limit these spots, we can reduce the size of the patches, which will force the algorithm to denoise each tile of the checkerboard individually.

Experiments on the Non-Local Means Denoising

The second article deals with Non-Local Means Denoising. This algorithm aims at replacing a patch by the average of several other patches. These patches need to be close in space and in colors.

We used the same images with the same standard white noise as before.

Natural image

Figure 9: Original image

Figure 10: Noisy image

Figure 11: Non-local means denoised image (PSNR : 30.04dB)

Figure 12: Zoomed in non-local mean denoised image with $\sigma = 65$

Contrasted image

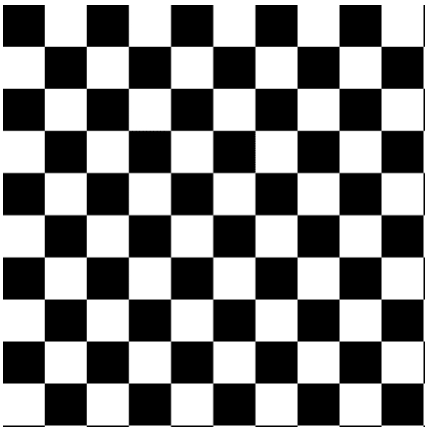

Figure 13: Original image

Figure 14: Zoomed in non-local mean denoised image (PSNR: 30.99dB)

Non-repeating image

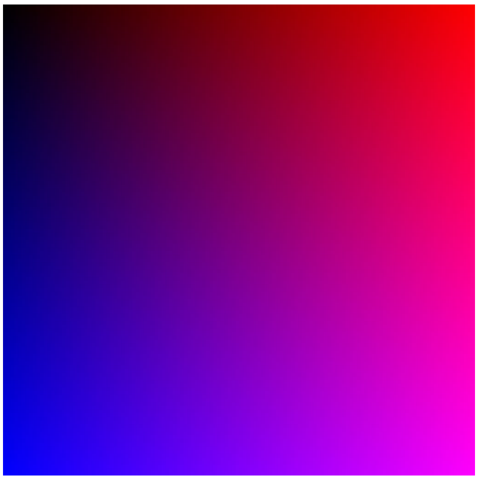

Figure 15: Original image

Figure 16: Zoomed in non-local mean denoised image (PSNR: 38.64dB)

Interpretation of the results:

The advantage of not using Fourier transforms in this algorithm is that no Gibbs oscillations can be seen, especially near the lamp post but also in the checkerboard image (see Figure 14). Thus, the large demarcations seem sharper.

On the other hand, this "algorithm" has some defects. First of all, the colours seem less intense and the details fade. This is due to the fact that this algorithm averages pixels and thus loses information. For instance, the cross walk completely disappeared in the street image. In addition, this algorithm causes lighter horizontal bands to appear. They are very visible on homogeneous areas, especially in the sky and on the road (with a stronger noise, see Figure 12). Unfortunately, I cannot modify the hyperparameters of the algorithm to explain in depth what is the reason for these horizontal lines.

We also notice that this algorithm makes tiles appear in an image without pattern. Indeed, if we look at the gradation image, we see that no patch can have a similar patch. The algorithm therefore replaces a patch directly with its average value, resulting in a checkerboard pattern in the Figure 16.

Conclusion:

First of all, we can notice that non-local means denoising is a simpler algorithm, more intuitive and with less hyperparameters than the Multi-Scale DCT denoising algorithm.

In terms of pure performance, Multi-Scale DCT denoising shows better results with a PSNR generally 1dB larger. If we look at the visual results, we notice that Multi-Scale DCT denoising can cause spots to appear if the patch size does not fit the image. These spots due to Gibbs oscillations are absent from the images denoised by non-local means denoising. However, the latter algorithm has two major shortcomings: it tends to make brighter discontinuous lines appear when there is a strong noise and it makes the images less intense, as each pixel becomes an average. Many details disappear. Moreover, the Multi-Scale DCT denoises the homogeneous area much better.

Thus, for an average user, if its camera has low noise, it is better to use the non-local mean denoising as the edges seem sharper. On the other hand, if its camera has high noise, the user prefers to have some oscillations rather than an image with very bright horizontal lines. Multi-Scale DCT denoising is better for the general public.