Lab 3 - Coded apertures

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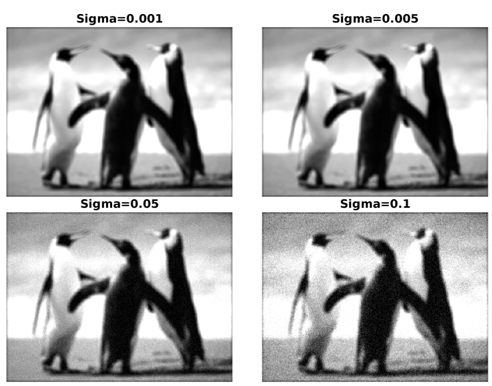
1 Blur Simulation and recover of focused image

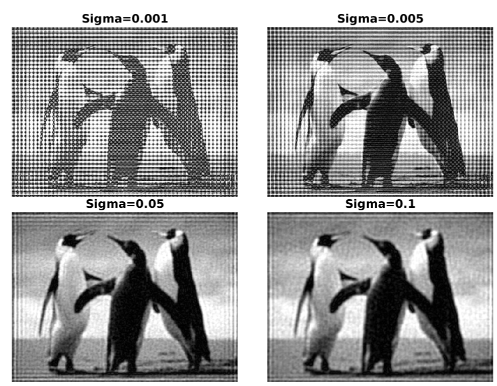
1.1 Noise levels and Blur size kernel variation

Noise level: To study the effect of changing the noisiness of the image (σ), a fixed kernel of disc size and radius of 5 pixels has been chosen.

In fig.1, the comparison between the different noise levels is done. It can be seen that, for very low sigmas ($\sigma = 0.001,\ 0,05$), the noisy image is not really that noisy. However, the reconstructed image from these images are really bad. This is because the inverse of the inversion of the very low noise kernels is very badly conditioned, and so, the results are very granular, as can be seen in fig.1b. However, in the case of the more noisy images, even if the noisy images look worse, the reconstructed images are quite good.



(a) Noisy images

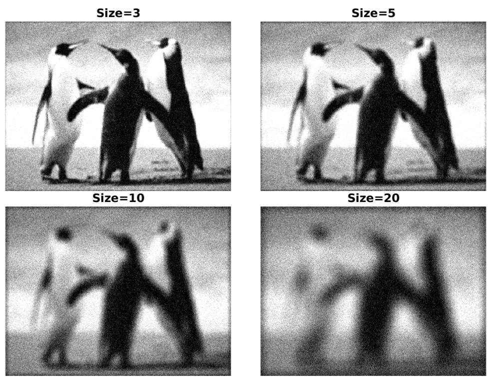


(b) Reconstructed images

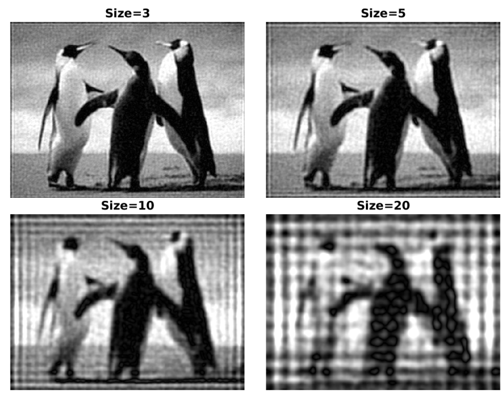
Figure 1: Noisy images and their reconstructions using different sigmas. All kernels are disc-shaped and have a radius of 5 pixels.

Kernel Size: To study the effect of the size of the kernel, a fixed noise level of $\sigma = 0.1$ has been chosen, as it has given us a good reconstruction in the previous test. In this case, the bigger the blur, the worse the reconstruction, as it can be seen in fig.2b.

Another interesting observation is that the reconstruction worsens near the edges and gets better in the center of the image. This is very noticeable for a size of 10. The probable reason behind this is that, as the kernel size increases, more pixels on the edges get their information ”thrown out” of the picture, and so, it is lost. And the bigger the kernel more pixels are affected, and the pixels already affected, lose more of the information.



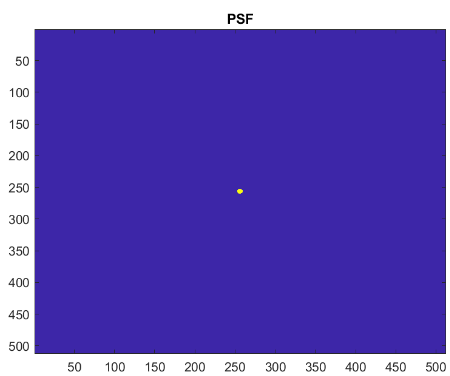
(a) Noisy images



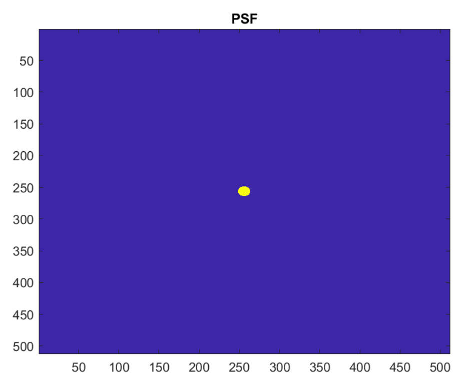
(b) Reconstructed images

Figure 2: Noisy images and their reconstructions using different kernel sizes. All kernels are disc-shaped. The size corresponds to the radius of the kernel in pixels. The sigma of all kernels is $\sigma = 0.1$.

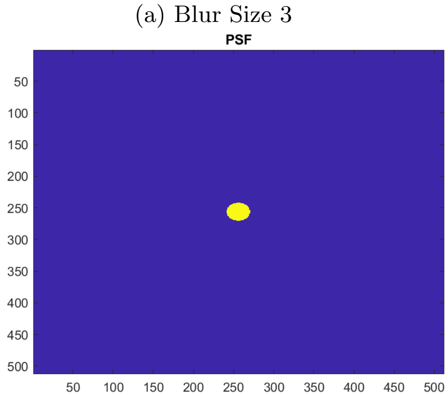
1.2 Show how the PSF varies with different focal lengths



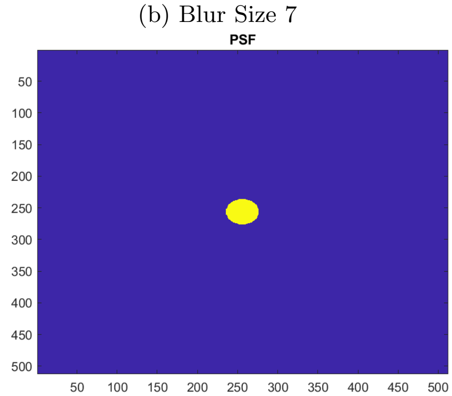
(a) Blur Size 3



(b) Blur Size 7



(c) Blur Size 14



(d) Blur Size 20

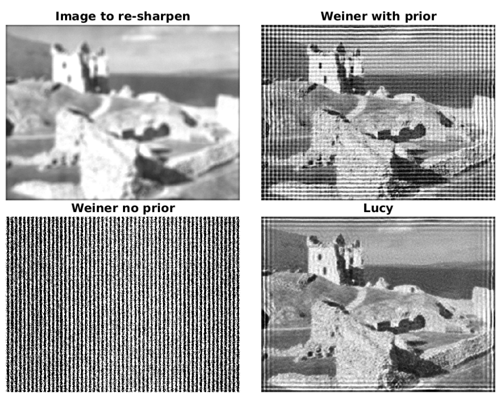
1.3 Different deconvolutions

We will be comparing three different deconvolution methods:

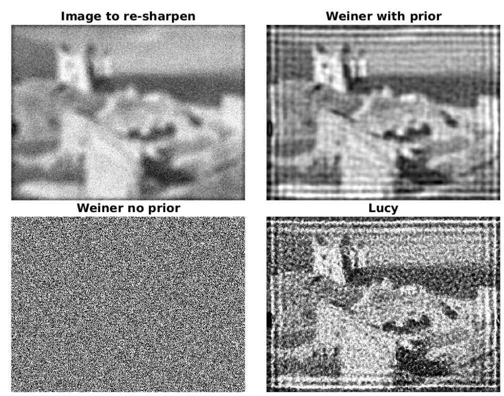
- The Weiner deconvolution with priors.
- The Weiner deconvolution without priors.
- Lucy deconvolution with 20 iterations.

To compare them, two different types of kernels will be used, a kernel of size 10 and noise of $\sigma = 0.1$, and a kernel of size 5 and $\sigma = 0.01$.

The blurred images and their corresponding reconstructions are shown in fig.4. It seems like, for more noisy images, the Weiner deconvolution works best. However, for less noisy images, the Lucy deconvolution seems to avoid the artifacts that appear on the Weiner approach. On the other hand, the Weiner deconvolution without any priors is unable to recover any image.



(a) Size of 5 and $\sigma = 0.01$



(b) Size of 10 and $\sigma = 0.1$

Figure 4: Different deconvolution strategies for different blurred images.

2 Power Spectra

When recovering pictures, the maintenance of the spectral amplitude of the image is highly important in order to reconstruct it, and obtain the sharped version of it.

In this section, the power spectra of the defocused images are plotted. This shows us how important the aperture kernel is, in order to keep high frequencies of the original image.

The ringing artifacts produced by the cirular aperture (Figure 5) is produced by the sinusoidal waves the kernel creates. This kills frequencies values as can be seen in the defocused X plot. Which force the line to reduce the number of spikes, hence losing information.

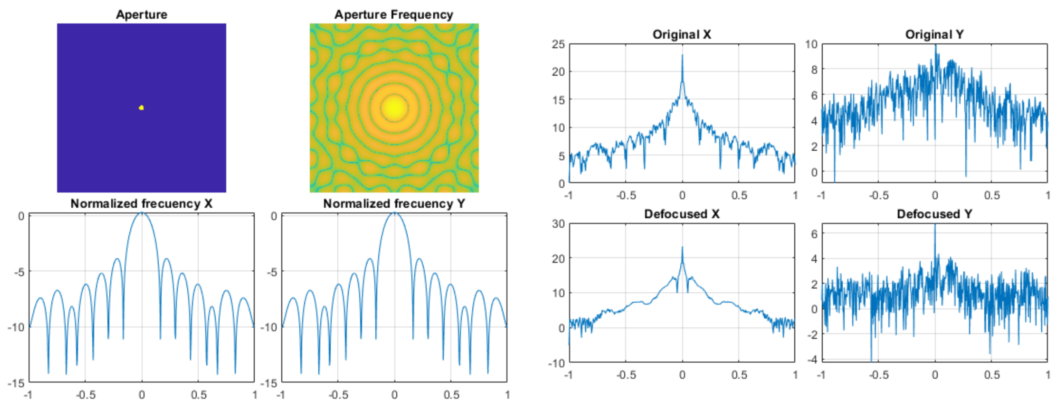


Figure 5: Circular aperture

The following three apertures has been created by optimisation problems solvers, where the goal was to recover the maximum information as possible.

We can see how the high frequencies are kept and the amplitude frequency of the image continues maintaining close to the whole information.

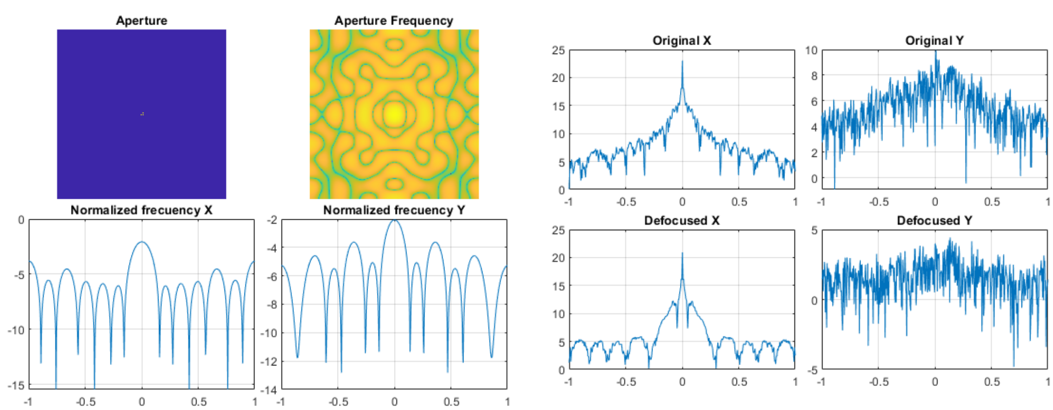


Figure 6: Levin aperture

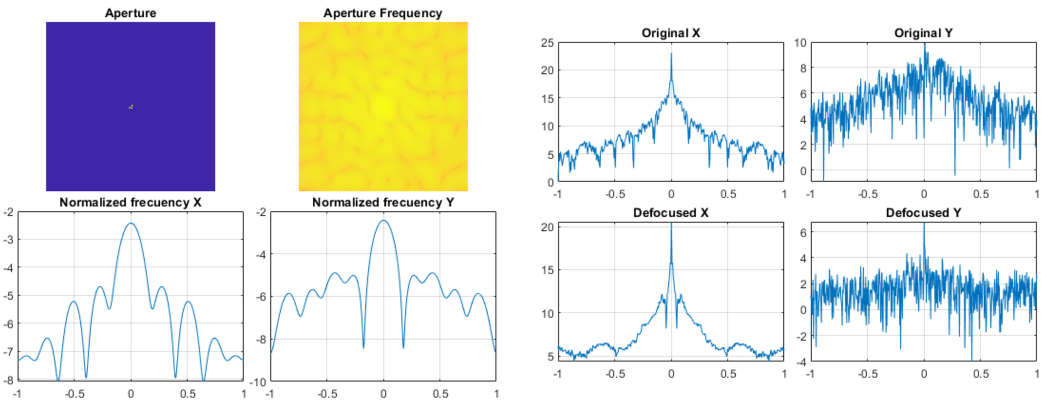


Figure 7: Raskar aperture

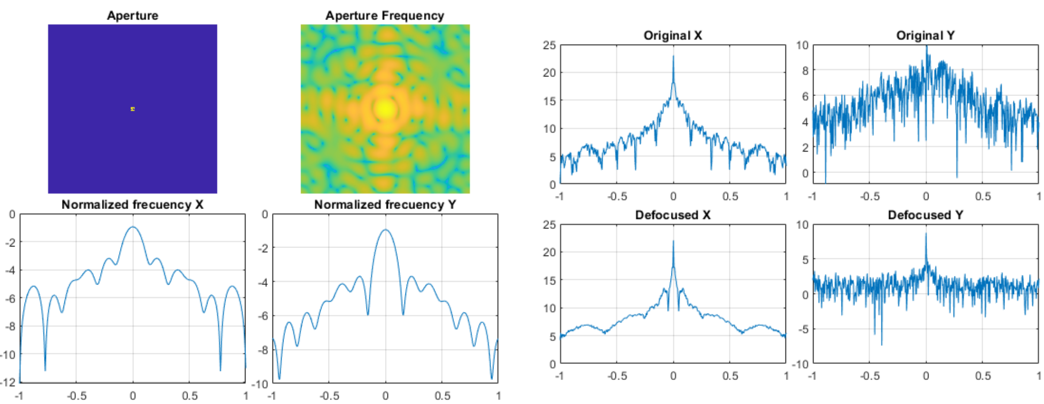
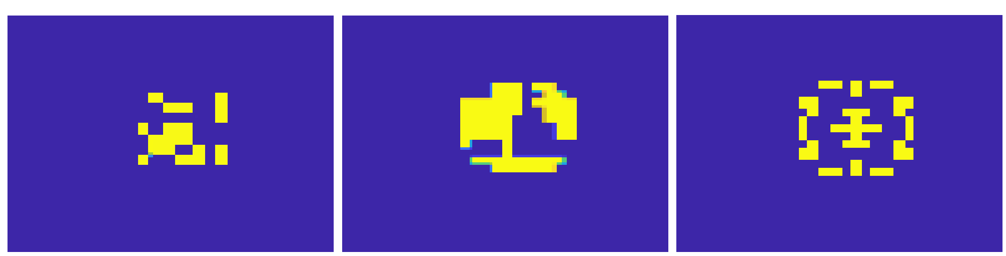


Figure 8: Zhou aperture

3 Coded Apertures

In this section we show the effects blurring and de-blurring images using different types of coded apertures; Raskar, Zhou and Levin.



(a) Raskar (b) Zhou (c) Levin

Figure 9: Apertures

For each aperture, 4 different combinations of noise and blur size have been applied. Two with same size and different noise, and two with different size but same noise.

Also, for each of the different combinations, the three reconstruction methods of section 1.3 have been used.

3.1 Raskar

The power spectra and aperture shape of the Raskar aperture are shown in fig.7. From the three apertures, it is the one that better resists the appearance of artifacts for low sigma values and size of 10, and coincidentally, it is the one that less looks like a disk.

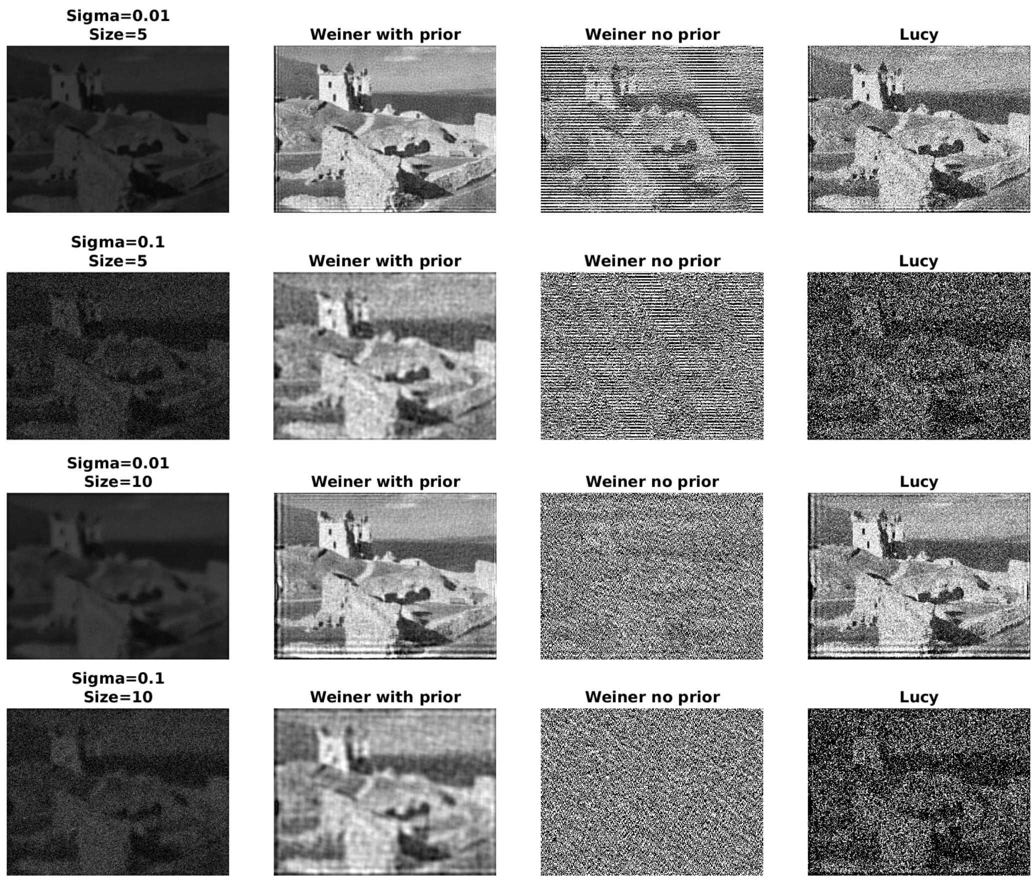


Figure 10: Raskar aperture

3.2 Zhou

The power spectra and aperture shape of the Zhou aperture are shown in fig.8. The noisy images from this aperture are the brighter ones, due to it being the one with more "open pixels" of the three. Another notable thing of this aperture is that, for the Weiner reconstruction with no prior, it shows the only "decent" result (at $\sigma = 0.01$ and size 5), but it is not clear to us why.

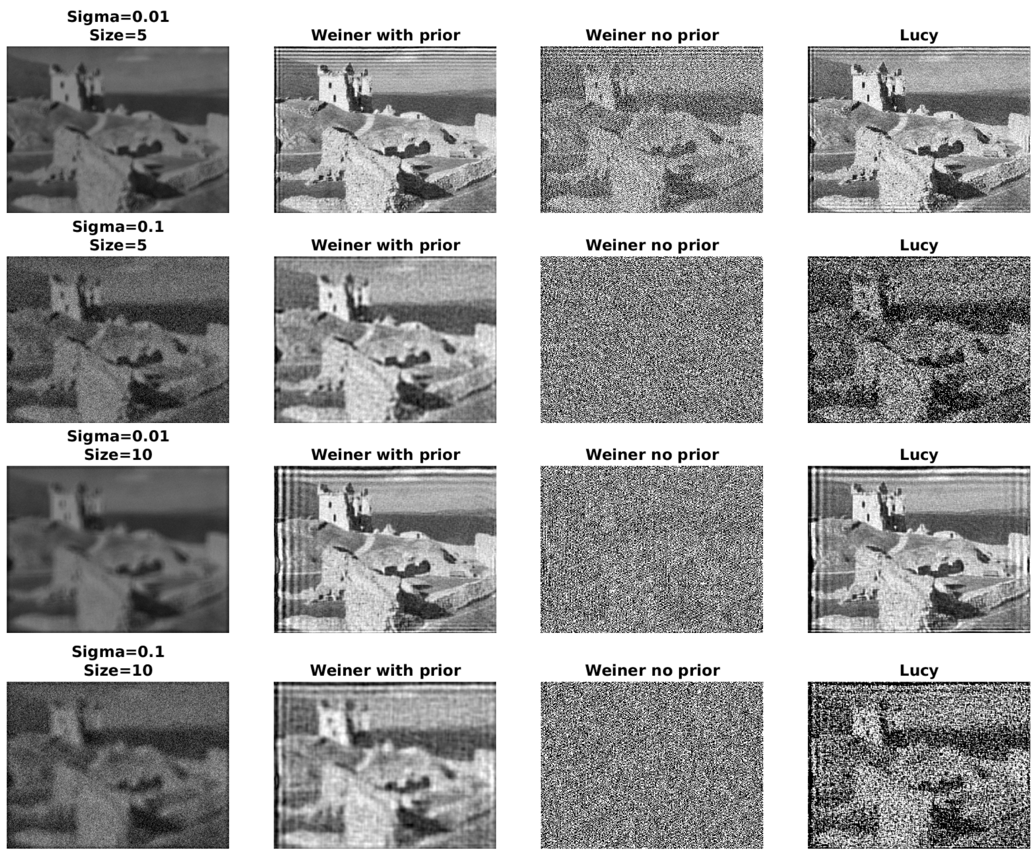


Figure 11: Zhou aperture

3.3 Levin

The power spectra and aperture shape of the Levin aperture are shown in fig.6. Comparing this aperture with the rest, we can see that, for low sigmas, it tends to create a more noticeable artifact across the image, something that has in common with the pure circular aperture. And looking at the spectrum (fig.6), we can see that it is also the one that looks the most like the circular one.

It is also interesting to note how the blurred image is also much darker, due to "less light" passing through the aperture.

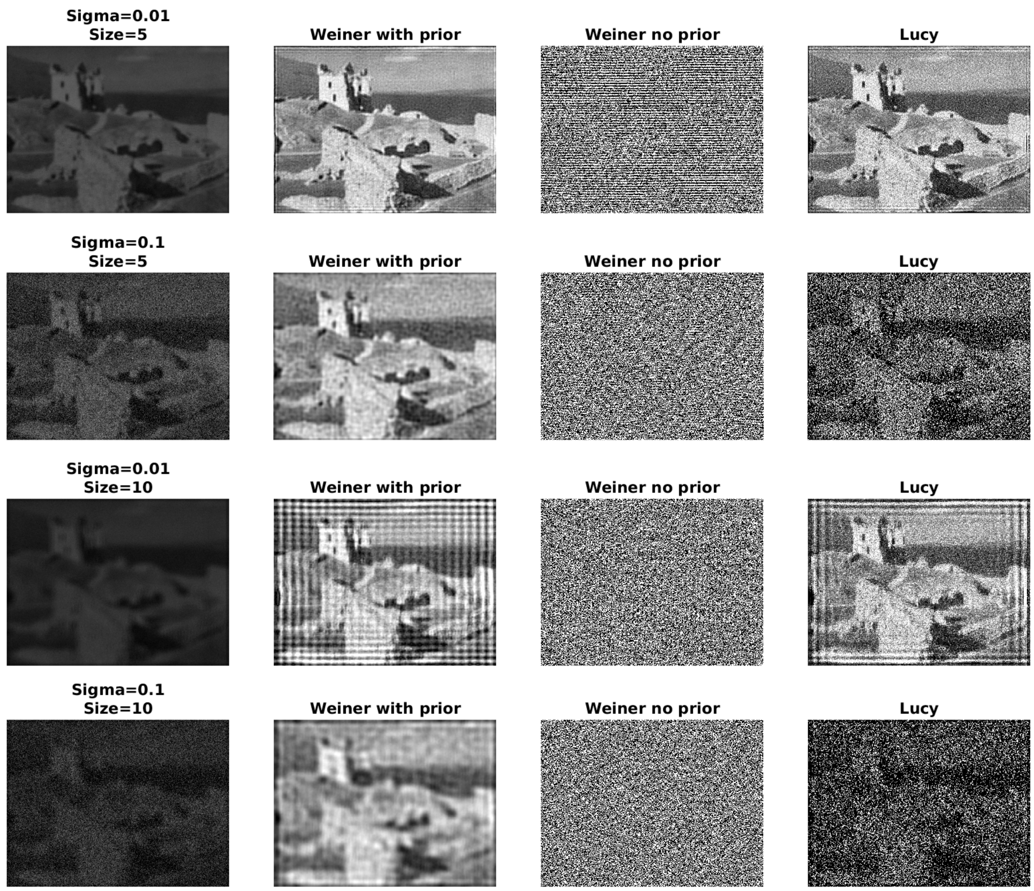
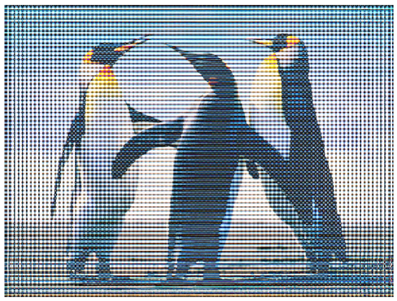


Figure 12: Levin aperture

4 Color images

Applying these techniques conserving the color scale of the image, can be done by processing each channel separated and then fusing them again.

The final result is:



(a) Circular Kernel

(b) Levin Kernel

(c) Raskar Kernel

(d) Zhou Kernel

As seen in the previous sections, Raskal and Zhou obtains the best sharpened images, by being kernels that optimize the amount of information that can be recovered from unsharped part of the image.