Computer Vision Course **(Due: 15 May 2020 [hbday to me])**

Image Filtering Lab #1

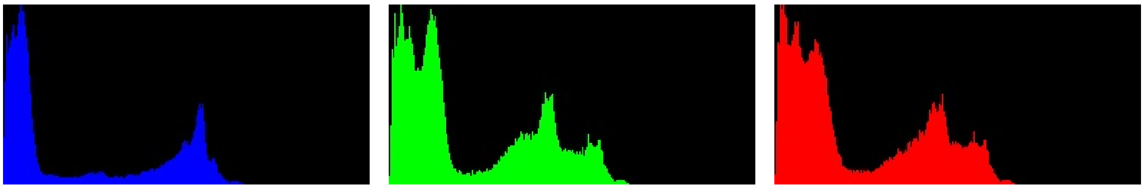
Instructor: Prof. Pietro Zauttigh *Name:* Elena Camuffo, *Id:* 1234370

Part 1 - Equalization of Histogram

Given an RGB input image, the first task provides an equalization of the histogram. This operation is performed first working on the RGB channels, one at a time, and then switching to Lab colorspace and working only on the luminance channel.

RGB equalization

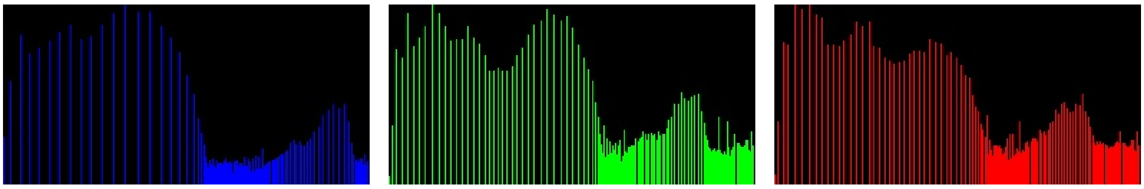
After separating the image into its three channels (BGR), the histogram is computed through the *CalcHist* function separately on each channnel. As histogram size is taken $h_s = 256$, while the range is set to $range = [0, 255]$. The initial histogram plots are shown in figure 1. The x-axis represent the *range* of intensities, while the y-axis represents the frequency of that intensity in the input image. It is possible to notice that the histogram plots are all concentrated in the left and central region, as the input image is very dark (figure 4a).



(a) Blue Channel (b) Green Channel (c) Red Channel

Figure 1: Resulting Histograms RGB.

Therefore, the equalization is performed using the function *EqualizeHist* separately on the three channels as well, and the result is shown in figure 2. The diagram values are here spread over the whole interval, indicating a more balanced lighting in the output image.

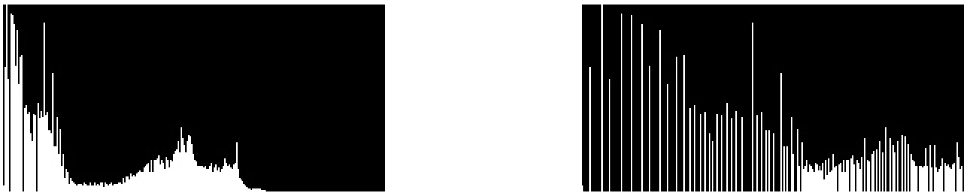


(a) Blue Channel (b) Green Channel (c) Red Channel

Figure 2: Resulting Histograms RGB equalized.

Lab equalization

To improve the quality of the result, a better colorspace is chosen. The procedure performed here is roughly the same as in the previous paragraph. The difference lies in the image colorspace, which is changed to *Lab*, and the only channel equalized is the Luminance (fig. 3). As in the previous result, also this diagram is initially concentrated in the first part of the range to spread out after equalziation.



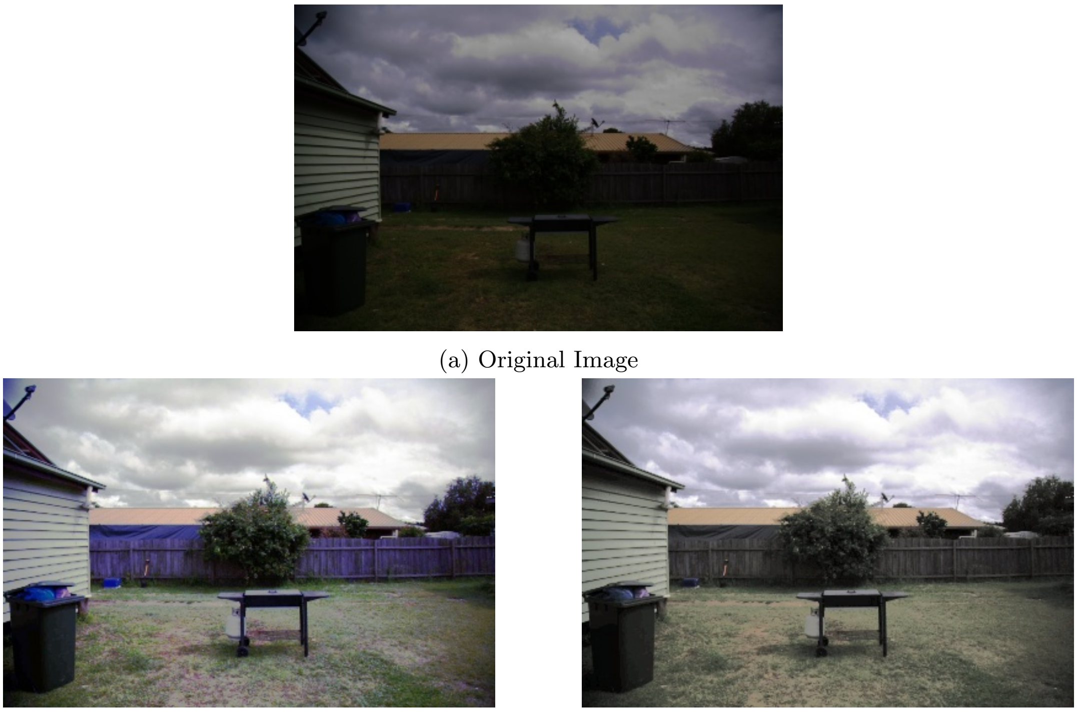
(a) Luminance Channel

(b) Luminance Channel equalized

Figure 3: Resulting Histogram of Luminance before and after equalization.

Conclusions

Figure 4 shows the original image and the resulting images with the two procedures. It is possible to notice that the equalization of the histogram brings a great improvent as regards the brightness of the image in both results.
The RGB image is even brighter, but little unnatural, while the Lab image seems to be more realistic and more natural in terms of colors.



(a) Original Image

(b) RGB equalization

(c) Luminance equalization

Figure 4: Comparison of the resulting images w.r.t. the Original one.

Part 2 - Image Filtering

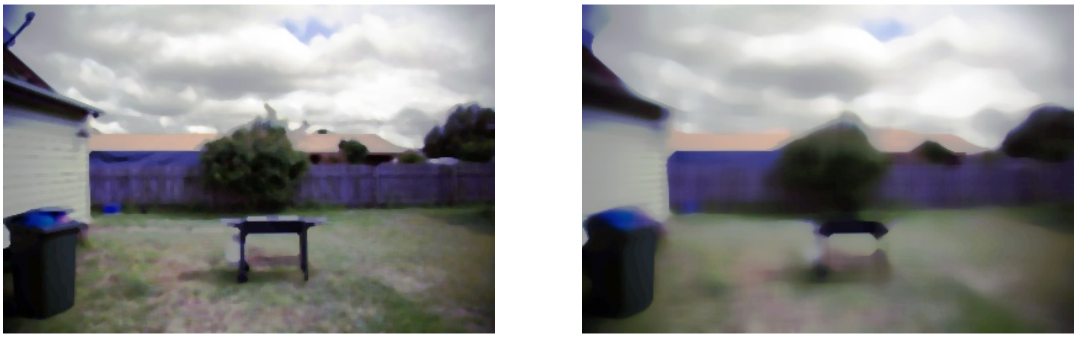
The image filtering is here taken into consideration. Three different filters are exploited, with different parameters values, in order to have a comparison among the results obtained this way.
The image used for the filtering is the result of the previous step, obtained through the RGB equalization.
The window size w_s is asked the user to be inserted, and in the example image shown here, it is set to $w_s = 9$ in advance.

Median Filter

The median filter is a non linear filter, typically used to remove *Salt and Pepper noise*, which has the following structure:

$$g(x, y) = median_{(s,t)\in R}\{f(s, t)\}$$

and its single parameter is the window size w_s.
The resulting image is shown in figure 5. It is possible to notice that as the window size becomes larger, the blur increases.



(a) Median filter $w_s = 5$

(b) Median filter $w_s = 15$

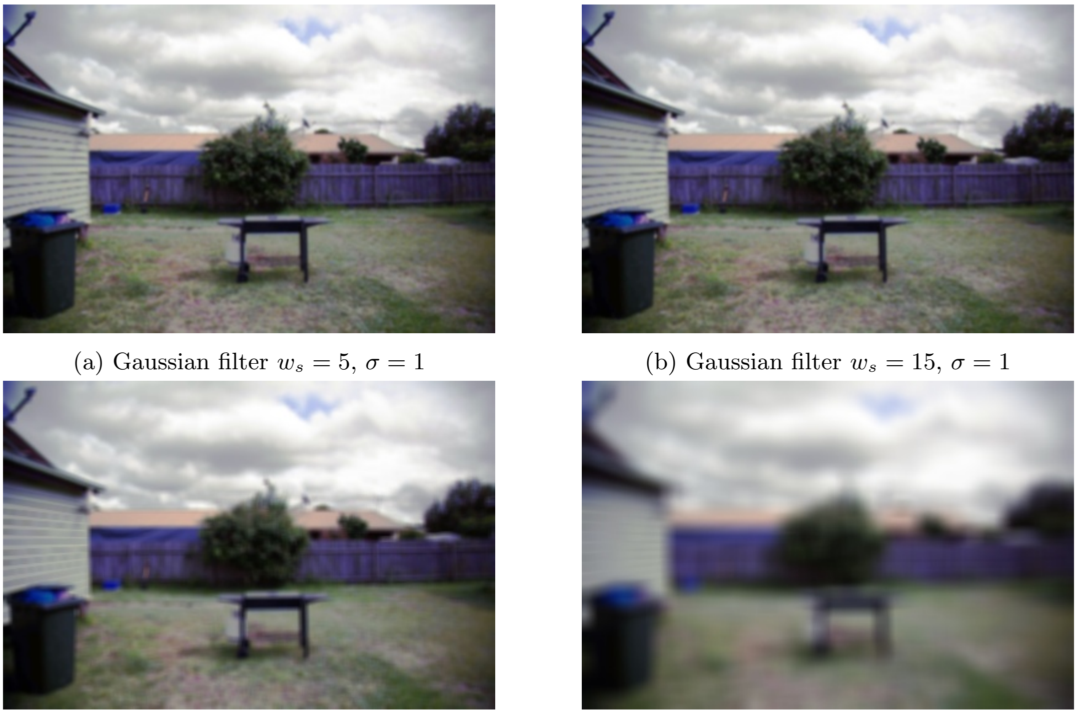
Figure 5: Median filter results. Blur increases when $w_s \uparrow$

Gaussian Filter

The Gaussian Filter is a linear filter (typically low-pass) having the following structure:

$$H(u, v) = e^{-\frac{D(u,v)^2}{2\sigma^2}}$$

Where $D(u, v) = \sqrt{(u - P/2)^2 + (v - Q/2)^2}$ and the parameters involved are the window size w_s, and the the standard deviation σ (tuned thanks to the placement of a trackbar).
The resulting image is shown in figure 6. It is possible to notice that for large values of σ the blur increases. The window size, on the other hand doesn't affect too much the result for very small values of sigma, but increases exponentially the blur for large σ.



(a) Gaussian filter $w_s = 5$, $\sigma = 1$

(b) Gaussian filter $w_s = 15$, $\sigma = 1$

(c) Gaussian filter $w_s = 5$, $\sigma = 90$

(d) Gaussian filter $w_s = 15$, $\sigma = 10$

Figure 6: Gaussian filter results. Blur increases with $\sigma \uparrow$, $w_s \uparrow$

Bilateral Filter

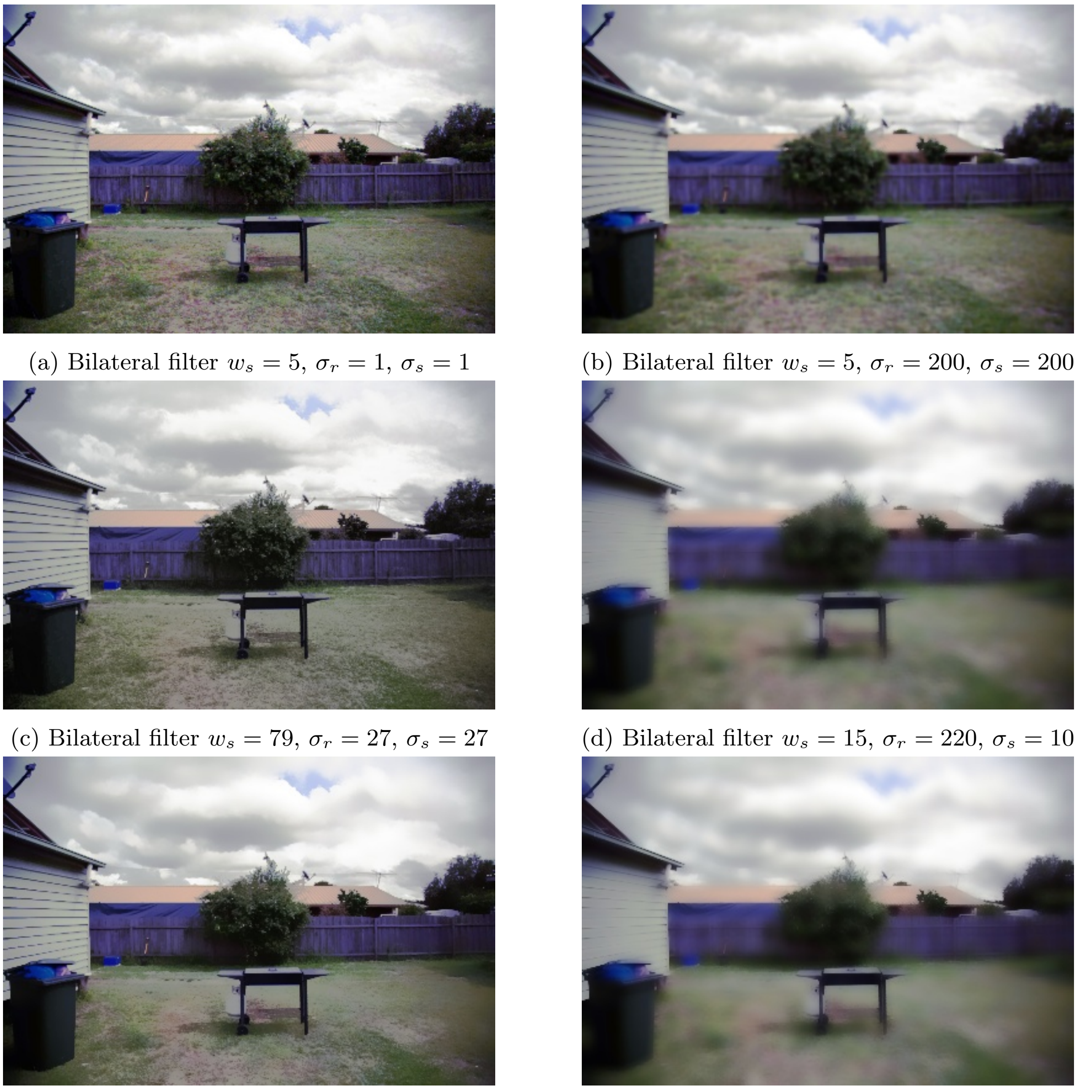
The Bilateral Filter is a quite recent method which aims at guarantee high quality in filtering. It is an edge-preserving filter and has the following structure:

$$BF[I]_{\boldsymbol{p}} = \frac{1}{W_r} \sum_{\boldsymbol{q} \in S} G_{\sigma_s}(||\boldsymbol{p} - \boldsymbol{q}||) G_{\sigma_r}(||I_{\boldsymbol{p}} - I_{\boldsymbol{q}}||) I_{\boldsymbol{q}}$$

Where $G_{\sigma_s}(\cdot)$ and $G_{\sigma_r}(\cdot)$ are Gaussians of parameters σ_r and σ_s. In additions to these two parameters (tuned thanks to the placement of trackbars), there is the window size w_s as well.
The resulting image is shown in figure 7. It is possible to notice that the image keeps always a quality level even higher than the images obtained with the previous filters. In particular, the blur occurs more with an increasing value of the σ_r parameter (figures 7d, 7f), while increasing the parameter σ_s keeps anyway the general shapes of the elements, with a loose in the finer structures (figure 7e). As in the Gaussian filter, a small value of the window size doesn't make relevant changes in the result, but for large window sizes the other changes are emphasized.

Conclusions

As just pointed out, the Bilateral filter is the one which allow us to obtain the best results in terms of visual quality, and keeps acceptable levels also with quite high values of the parameters.
In particular, setting well the value of σ_s allow to reveal the most relevant structures in the image, removing noise and avoiding excessive blurring.



(a) Bilateral filter $w_s = 5$, $\sigma_r = 1$, $\sigma_s = 1$

(b) Bilateral filter $w_s = 5$, $\sigma_r = 200$, $\sigma_s = 200$

(c) Bilateral filter $w_s = 79$, $\sigma_r = 27$, $\sigma_s = 27$

(d) Bilateral filter $w_s = 15$, $\sigma_r = 220$, $\sigma_s = 10$

(e) Bilateral filter $w_s = 15$, $\sigma_r = 35$, $\sigma_s = 420$

(f) Bilateral filter $w_s = 15$, $\sigma_r = 160$, $\sigma_s = 280$

Figure 7: Bilateral filter results. Blur increases with $\sigma_r \uparrow$, finer details are destroyed when $\sigma_s \uparrow$, $w_s \uparrow$ emphasizes changes