EE-550 | **Laboratory 3**
Edge and contour detection

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1 Template method

In the noiseless case the output given by the three templates are very similar, however it can be noticed that when Roberts is applied the output image is slightly noisier in the area where the texture is not uniform, like the hat of the girl in 'lena.png' or the grass in 'road.png'. Moreover, edges are thicker and more defined when either Sobel or Prewitt templates are used. At this stage there are no major differences between Sobel and Prewitt. When Gaussian noise is applied, it is even more evident that Robert template is more sensible to noise. The image, for a standard deviation $\sigma = 25$, is completely distorted and the original items (the grains of rice in 'rice.png') are not distinguishable. The noise affected the efficacy also of Prewitt and Sobel templates yet to a lesser extent. In this case Prewitt template gave a slightly less noisier result.

This method is the faster and less complex one compared to the methods described in the following sections.

2 Compass operator

To construct the kirsch operator function I applied the following formula:

$$h_{n,m} = \max_{z=0,\dots 7} \sum_{i=-1}^{1} \sum_{j=-1}^{1} g_{ij}^{(z)} \cdot f_{n+i,m+j}$$

where z refers to the z-th Kirsch mask $g^{(z)}(k,l)$.
When compared to the Sobel template method, the Kirsch operator does not add more definition to the edges of the image. The results between the two methods are similar also in the noisy case.

This method is the most time consuming method among all the others, due to the fact that it requires the computation of one sub-matrix for each pixel.

3 Laplace operator

The results obtained with the Laplace operator are different from the previous ones: the edges have uniform thickness, they are thinner and there are many closed contours. Moreover, after an edge is detected by the zero-crossing operation I had to add a further threshold on the difference between the pixels under analysis in order to reduce the number of edges and to avoid the "spaghetti effect". In the noisy case new contours appears but the main edges are still distinguishable even with $\sigma = 25$, this makes the Laplace operator (thanks to the filtering operation with a Gaussian filter) the less sensitive to noise when compared to the other methods and using 'rice.png' image.

Even if it involves only one kernel, it has a higher computational cost than the template method because of the zero-crossing detection.

4 Frei-Chen method

In the images processed applying the Frei-Chen method the edges are represented by clusters of white dots. The contours and the edges are less defined and the presence of individual white dots spread out on the whole image makes the edge identification even harder. This method is indeed more sensitive to subtle edges, hence to delete the isolated dots could improve the result. This method is also more sensitive to the noise as it can be seen in the case for which the standard deviation is 25. In this case the shapes of the grains are more difficult to be detected than in any of the previous case.

To perform edge detection with this method takes less time than the Laplace and the compass operators. The most computationally expensive operations that it involves are the nine convolutions and the two summations.

5 Conclusions

To sum up, among the template methods Sobel and Prewitt templates performed better than Roberts and their results are similar to those obtained by the Kirsch compass operator, characterized by thick edges. The Laplace operator produced thinner edges and in some area the items are difficult to recognize. However, thanks to the Gaussian filter it showed to be less sensitive to noise than the other methods, even though this could be related to the specific image that has been used ('rice.png') which was particularly simple and whose objects have clear and defined contours. If more complex images are used, the Laplace operator shows highly distorted results with broken contours and fake edges. Finally, the Frei-Chen method is more sensitive to subtle edges and to noise.

In terms of complexity, the template method is the simplest and faster one, while the compass and Laplace operators are the ones that require more computations and time.