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Digital Image Processing
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Lab 3 – Image Enhancement with Linear Filters

1 Introduction

Similar to the previous lab, this week we are also dealing with image enhancement. Yet, we are now focusing on applying linear filters to the image.

2 Learning Objectives

- You know how to implement simple filters (high pass, low pass) in spatial domain.
- You know how to appropriately deal with boundary pixels.
- You know which filters to use to sharpen an image.
- You know how to apply a filter to an image.

3 Tasks

3.1 Home-Grown Low-Pass Filter

In this exercise you will implement two different low-pass filters and apply them to two digital images—`xRayChest.tif` and `bloodCells.tif`.

1. In a first step, create two 3×3 spatial low-pass filters—an averaging filter with impulse response h_m and a Gaussian filter ($\sigma = 0.85$) with impulse response h_G, where

$$h_m = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \text{ and } h_G = \frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}.$$

2. Apply this filter mask to the given images and compare the results between average and Gaussian filtering.

Hints: An easy way to create the averaging filter is `np.zeros(...)`. A convenient way to apply the filter to the image is using the `convolve2d(...)`-command from the `scipy.signal` package.

3.2 Simple High-Pass Filter

A very easy way to implement a high-pass filter is to subtract the low-pass-filtered version of an image from the original image.

1. Apply the low-pass filters to both given images.
2. Create a high-pass filtered version of the original images by employing the previously mentioned subtraction procedure. Make sure you use the correct data types.
3. Convert all images to `uint8` and compare the original image to the high-pass and low-pass version. Discuss the impact that each filter has on the image.

3.3 Image Sharpening

A traditional way to sharpen an image is by combining the original image with an image where the edges have been enhanced. This edge enhancement can be achieved with Laplace filters. There are various ways to implement a Laplace filter, and two possible implementations are given below:

$$h_1 = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \text{ and } h_2 = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}.$$

1. Apply any of the two given filters to the original image.
2. Check how the filter changes the image.
3. Try to sharpen the original image by combining it with the filtered image.
4. What happens if you replace the Laplace filter by a high-pass filter of your choice?
5. Check if you obtain better results if you use Gaussian unsharp masking instead of the Laplace filter.

3.4 For Those Who Dare—Median Filter

The image `cellsSandP.tif` contains salt-and-pepper noise.

1. Try to remove this noise with an averaging filter.
2. Now, apply a median filter instead. How does the computation time compare to that of a linear filter?