Technische Universität Berlin

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Digital Image Processing

Exercise 03

Jochen Jacobs - 373163
Herbert Potechius - 353420
Sourabh Raj - 397371
Sangeetha Reji - 406043

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1 Theory

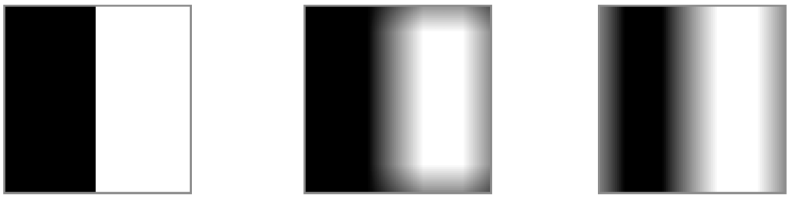

Figure 1: Convolution in spatial domain and multiplication in frequency domain

A moving average filter was applied to the image in Figure 1a). Figure 1b) shows the result, if the convolution is carried out in spatial domain, Figure 1c) if the convolution is carried out as multiplication in frequency domain.

1. **Explain which assumptions lead to the "unexpected" border values in each image and why they are different for both methods**

   To get the result in Figure 1b), pixels outside of the image of Figure 1a) will be set to 0 (black). If we apply for example a 3x3 boxfilter on the upper right corner of the image (255, white pixel), we have to inlude 8 surrounding pixels (3 white pixels of the image itself and 5 black pixels outside of the image). The resulting pixel will be grey (intensity of 113), see Figure 1b).

2. **What steps are necessary for the convolution in spatial domain to produce the result in Figure 1c)?**

   To get the result in Figure 1c), we have to change the border handling. We don't use a static value anymore, but we repeat the pattern of Figure 1a) outside of the image, see Figure 2.

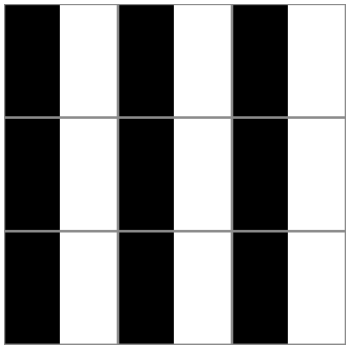

Figure 2: Borderhandling: repeat image pattern; *Note: grey lines just for visualise the repetition*

3. **What steps are necessaary for the convolution by multiplication in frequency domain to produce the result in Figure 1b?**

   Depending on the filtersize, we have to copy the image in a bigger image, which is completely black and center it. After the DFT of the kernel and the image, the multiplication of the resulting spectrum and the IDFT of the resulting product, we have to crop the resulting image to its original size.

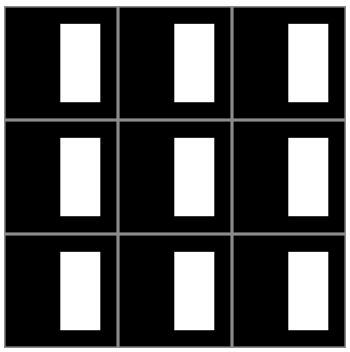

Figure 3: Borderhandling: repeat image pattern with black border; *Note: grey lines just for visualise the repetition*

4. **Explain the behaviour of Figure 2 and 3.**
   Note: For this experiment the following image- and filter sizes were used:
   Image-sizes: 64x64, 128x128, 256x256, 512x512, 1024x1024
   Filter-sizes: 5x5, 9x9, 13x13, 17x17, 21x21, 25x25, 29x29, 33x33, 37x37, 41x41

   In the convolution in the spatial domain, we have to slide the kernel over the whole image and have to apply the filter for each pixel, i.d. if we increase the number of pixels, the computation time increases as well. If we apply a NxN filter per pixel, we have to execute NxN multiplications (for the sourrounding pixels per current pixel), i.d. if we increase the filter size, the computation time increases.

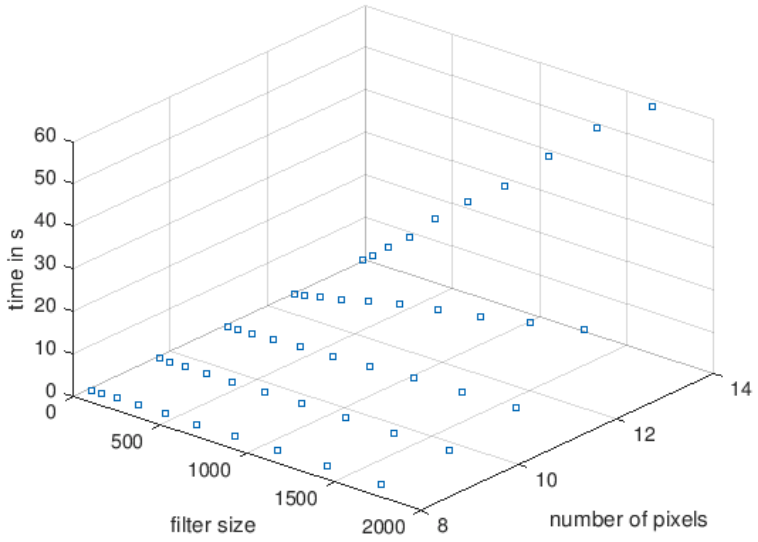

Figure 4: Convolution in spatial domain

For the convolution in frequency domain, we have to copy the kernel into a matrix, which has the same dimension as the image, i.d. the filter in frequency domain, which we apply to a specific image, has always the same size (independent of kernel size). If we apply filters with different sizes to the image, the computation time doesn't change much.
In frequency domain, the convolution is performed by component-wise multiplication of the image-spectrum and the filter-spectrum, i.d. if we increase the number of pixels, the computation time increases.

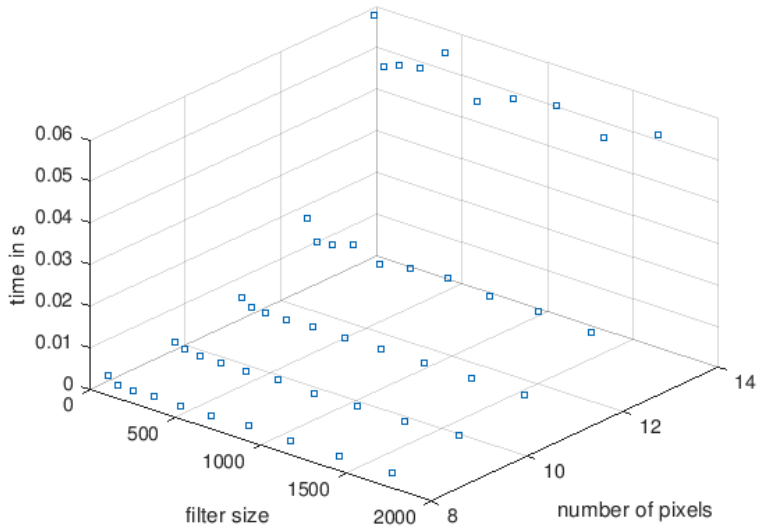

Figure 5: Convolution in frequency domain

Image Sources

- *Figure 1*: Digitial Image Processing - Exercise Sheet 03 - Page 25