ISSN 2224-087X. Електроніка та інформаційні технології. 2019. Випуск 12. С. 55–63
Electronics and information technologies. 2019. Issue 12. P. 55–63

УДК681.3.01+681.325 DOI: https://doi.org/10.30970/eli.12.6

METHOD OF SPACE IMAGE IMPROVEMENT BY USING SPATIAL OPTICAL MASK AND FREQUENCY FILERS.

I. Polovynko, A. Kashuba

Ivan Franko National University of Lviv,
50 Drahomanov St., UA–79005 Lviv, Ukraine
polovynkoi@gmail.com , AndriyKashuba07@gmail.com

Simple but effective program for the improvement of quality of space images, which is based on spatial and frequency filtration with a variety of filters, is provided are present. The theory of creating optical masks, which consists in using a convolution operation, is described. As an example, Gauss smoothing filters are considered. Practical part of this work was realized by using Python 3.7.4 program language in the environment Visual Studio 2017 Community Edition. Some programs where realized by using Jupyter Nonebook. This are presented 8 spatial filters. Also frequency filtering is performed by using Lowpass and Highpass filters at different fitting parameters. As an example for implementation of this program, the image space photography of Defense monastery of St. Basil the Great was taken. The results of filtering the image in the frequency range by using Lowpass and Highpass filters at different fitting parameters are shows, that it is better to apply frequency filtering after spatial selection in certain areas. In particular, for the case of image filtering with Highpass filters, remains of lost defensive walls of Defense monastery of St. Basil the Great are clearly visible.

Keywords: Gaussian functions, image space images, lowpass and highpass spatial filters. frequency filters, convolution operation.

Introduction.

With the development of computer technology [1]-[9] there are new opportunities for better image processing. Moreover, this applies not only to the visible range of electromagnetic radiation but also to the infrared, ultraviolet, X-ray and microwave range. However, the most effective remains the registration in the visible range (430-790 nm). This is primarily due to the structure of the human eye, which can distinguish up to $1.6*10^7$ different color shades. It should also be noted that the qualitative processing of optical images is a prerequisite for machine vision. In this paper spatial methods of image processing are developed on the example of cosmic imaging using a variety of masks. There are many different programs that allow you to enhance the images taken from outer space. However, most of them are either super-complicated or perform a limited number of operations. So in the presented work a simple but effective program for the improvement of quality of space an image, which is based on spatial filtration with a variety of filters, is provided.

Masks for image processing are built on the basis of gradation correlation. From a mathematical point of view, they provide a link to the brightness of images before and after transformations. More general communication gives the convolution theorem [10]-[12]. The discrete convolution of two functions and h(x,y) of size M□N is denoted by f(x,y)*h(x,y) and is defined by the expression:

$$f(x,y)*h(x,y)=\frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}f(m,n)\cdot h(x-m,y-n) \quad (1)$$

If ticked *F(u,v)* and *H(u,v)* the Fourier transforms of *f(x,y) and h(x,y)*, respectively, one-half of the convolution theorem simply states that and *F(u,v)H(u,v)* constitute a Fourier transform pair. This result is formally stated as:

$$f(x,y)*h(x,y)\Leftrightarrow F(u,v)H(u,v) \quad (2)$$

Conversely, the expression on the right can be obtained by taking the forward Fourier transform of the expression on the left. An analogous result ts that convolution in the frequency domain reduces to multiplication in the spatial domain, and vice versa:

$$f(x,y)h(x,y)\Leftrightarrow F(u,v)*H(u,v) \quad (3)$$

These two results comprise the convolution theorem. It is important to keep in mind that there is nothing complicated about what has just been stated. Main filters used to improve the images are: ideal low-pass filters, Gaussian, Butterworth, and Laplace. As an example we take into account filters based on Gaussian functions. Its main property is that both the forward and inverse Fourier transforms of a Gaussian function are real Gaussian functions. We will limit the discussion here to one variable to simplify the notation. Two-dimensional functions are similar. The Gaussian filter function given by the equation:

$$H(u)=A\cdot e^{-u^2/2\sigma^2}, \quad (4)$$

where σ is the standard deviation of the Gaussian curve. The corresponding filter in the spatial domain is:

$$h(x)=\sqrt{2\pi}\sigma A e^{-2(\pi\sigma\chi)^2}. \quad (5)$$

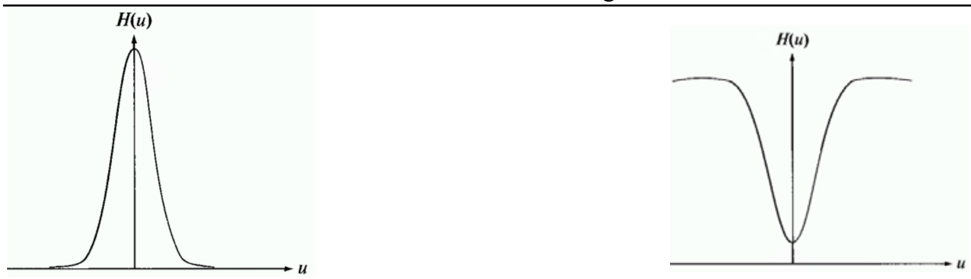
A plot of a Gaussian filters in the frequency domain is shown in Fig. 1(a, b). The corresponding filters in the spatial domain is shown in Fig. 2(a, b). Our interest is in the general shape of h(x), which we generally want to use as a guide to specify the coefficients of a smaller filter in the spatial domain. A glaring similarity between the two fillers is that all the values are positive in both domains. Thus, we arrive at the conclusion that we can implement lowpass filtering in the spatial domain by using a mask with all positive coefficients. Two of the masks are shown in Fig. 2(a). The narrower the frequency domain filters, the more it will attenuate the low frequencies, resulting in increased blurring. In the spatial domain this means a wider filter, which in turn implies a larger mask.

More complex filters can be constructed from the basic Gaussian function of Eq. (5). For instance, we can construct a highpass filter as a difference of Gaussians as follows:

$$H(u)=Ae^{-u^2/2\sigma_1^2}-Be^{-u^2/2\sigma_2^2}, \quad (6)$$

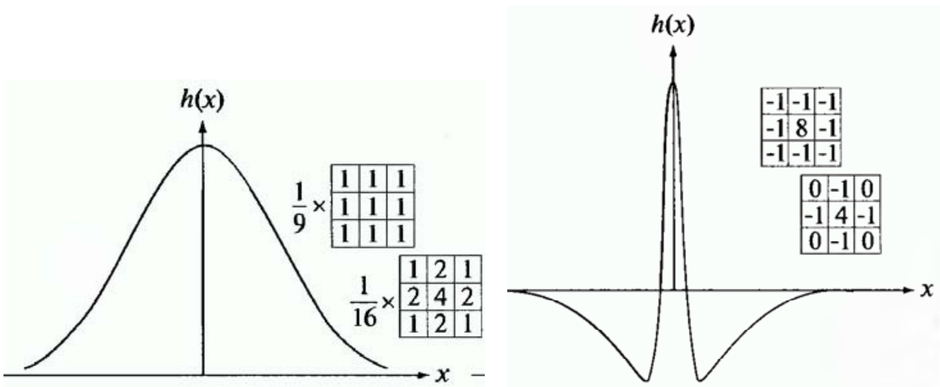
with $A \geq B$ and $\sigma_1 > \sigma_2$. The corresponding filter in the spatial domain is:

$$h(x)=\sqrt{2\pi}\sigma_1 Ae^{-2\pi^2\sigma_1^2x^2}-\sqrt{2\pi}\sigma_2 Ae^{-2\pi^2\sigma_2^2x^2} \quad (7)$$



a b

Fig. 1. (a)-Gaussian frequency domain Lowpass filter and (b) - Gaussian frequency domain Highpass filter.



a b

Fig. 2. Corresponding Lowpass spatial filter (a) and Highpass spatial filter (b). Two of the masks for Lowpass and Highpass filtering are shown ine the inserts

Plots of these two functions are shown in Figs. 1(b) and 2 (b), respectively. We note again the reciprocity in width, but the most important feature here is that the spatial filter has both negative and positive values. In fact, it is interesting to note that once the values turn negative, they never turn positive again. Two of the masks for Lowpass and Highpass filtering are shown ine the inserts of Fig.2(a) and 2(b) respectively.

Results.

Image filtering was done by two methods. The first method was to use already head masks. In the second case, the filtering was performed in the frequency domain using a program written on Python 3.7.4 by using internal functions.

Fore the implementation of these methods, the image space photography of Defense monastery of St. Basil the Great [13] was used and depicted on Fig. 3.

ISSN 2224-087X. Electronics and information technologies. 2019. Issue 12

Fig. 3. Part of the space photography of St. Basil the Great Defense monastery.

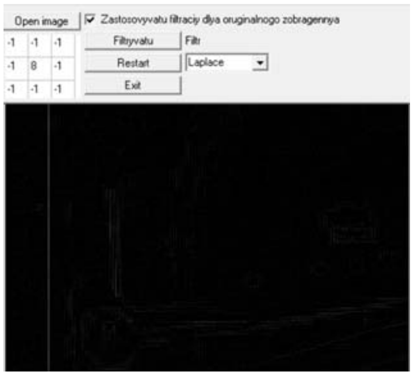


Fig. 4. Laplase filtration of original image.

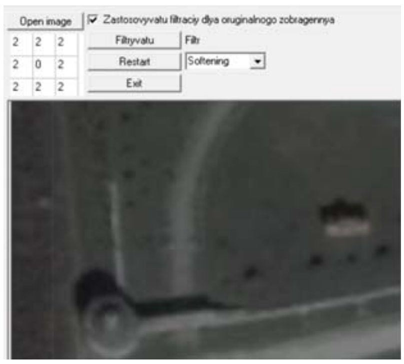


Fig. 5. Lowpass (Softening) filtration of original image.

3	3	3
3	8	3
3	3	3

(a)

-1	-1	-1
-1	9	-1
-1	-1	-1

(b)

0	-1	0
-1	5	-1
0	-1	0

(c)

Fig. 6. Mask for Spot (a) Hipass (b) and High Pass (c) filtration of the original image.

ISSN 2224-087X. Electronics and information technologies. 2019. Issue 12

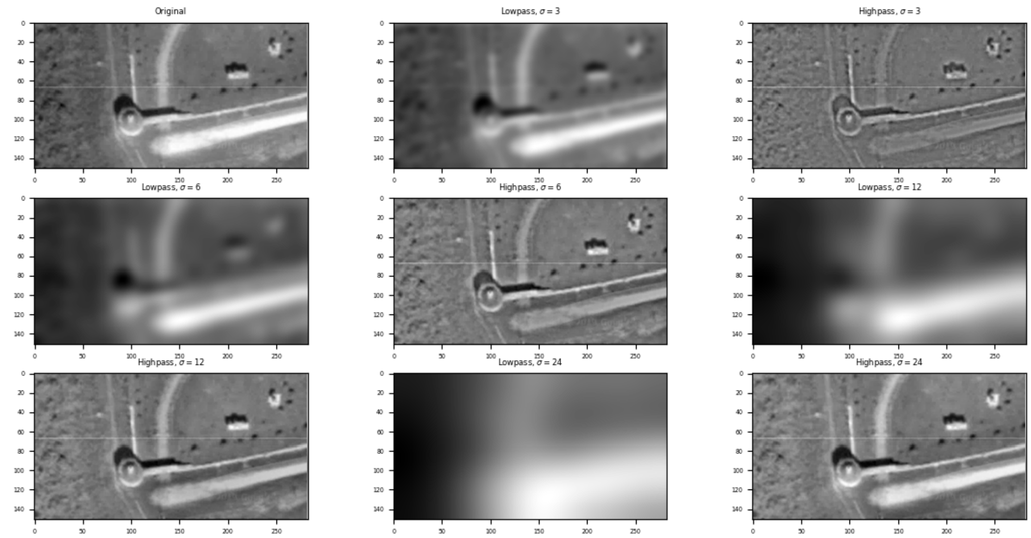


Fig.7. The results of filtering the image in the frequency range by using Lowhass and Highpass filters at different fitting parameters σ.

On the Fig.4 Laplase filtration of original image is presented. The processing of the initial image is called the Laplace transform. In the upper left part of the figure is a mask that corresponds to Laplace transformation. As it should be expected this transformation sharply emphasized the edges of the image. On the fig.5 we can see Lowpass (Softening) filtration of original image. A smoothing filter caused to defocus the image. Defocusing may be used as the preliminary step of image processing for example, to delete small details before discovering large objects, or to eliminate gaps in lines or details. In any case the smoothing filters are used to suppress the noise. On the fig.6 the so cold Spot, Hipass and High Pass masks are presented. In the case of our image (fig.3), they do not provide a special improvement. At figures 7, the results of filtering the image in the frequency range by using Lowhass and Highpass filters at different fitting parameters σ are presented. As the last figure shows, that Lowhass filters are effective for small values of fitting parameters (σ ≤ 12).On the contrary, for Highpass filters, better separation is observed at σ ≥ 12.

Conclusions.

An analysis of the effects of filters on the image has shown that each of them reveals certain features of this image. When it comes to perception with the help of the human eye, then the most useful is Lowpass or Softening filtration (Fig. 5). That is why, because, the output of a smoothing, linear spatial filter is simply the average of the pixels contained in the neighborhood of the filter mask. For these reason such filters sometimes are called averaging filters [10], [12]. The idea behind smoothing filters is straight forward, by replacing the value of every pixel in an image by the average of the gray levels in the neighborhood defined by the filter mask. This process results in an image with reduced. “sharp” transitions in gray levels. Because random noise typically consists of sharp transitions in gray levels, the most obvious application of smoothing is noise reduction. However, edges (which almost always are desirable features of an image) also are characterized by sharp transitions in gray levels, so averaging filters have the undesirable side effect that they blur edges.

By using of other filters which are proposed in the work, an opportunity has been maid, to reveal another important features of the image. For example, when applying a Sharpen filter, you can see more clearly the contours of the defensive walls. The results of filtering the image in the frequency range by using Lowpass and Highpass filters at different fitting parameters σ are shows, that it is better to apply frequency filtering after spatial selection in certain areas. In particular, for the case of image filtering with Highpass filters (σ = 24), remains of lost defensive walls are clearly visible.

However, as seen from the original drawing (Fig. 3), a significant role in image distortion arises due to noise. The problem lies in the fact that the main sources of pseudo-digital damage occur in the process of receiving it as well as in the process of transmission. So further efforts will be associated with restoring images by taking a noise.

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Supplement. An example of a program written on Python 3.7.4 by using internal functions.

```
import matplotlib.pyplot as plt
plt.rc('xtick', labelsize=4.5)
plt.rc('ytick', labelsize=4.5)
plt.rc('axes', titlesize=6)
import numpy as np
      from scipy import ndimage
       from PIL import Image
def plot(data, title):
   plot.i += 1
   plt.subplot(3,3,plot.i)
   plt.imshow(data)
   plt.gray()
   plt.title(title)
plot.i = 0
im1 = Image.open('photo.png')
im = im1.convert('L')
data = np.array(im, dtype=float)
plot(im, 'Original')

kernel = np.array([[1, 2, 1],
              [2,  4, 2],
              [1, 2, 1]])
highpass_3x3 = ndimage.convolve(data, kernel)
plot(highpass_3x3, 'Gauss Low Pass Filter (3x3)')
kernel = np.array([[2, 7, 12, 7, 2],
              [7, 31, 52, 31, 7],
              [12, 52, 127, 52, 12],
              [7, 31, 52, 31, 7],
              [2, 7, 12, 7, 2]])
highpass_3x3 = ndimage.convolve(data, kernel)
plot(highpass_3x3, 'Gauss Low Pass Filter (5x5)')

kernel = np.array([[-1, -1, -1],
              [-1,  8, -1],
              [-1, -1, -1]])
highpass_3x3 = ndimage.convolve(data, kernel)
plot(highpass_3x3, 'Laplace High Pass Filter (3x3)')

kernel = np.array([[-1, -3, -4, -3, -1],
              [-3, 0, 6, 0, -3],
              [-4, 6, 20, 6, -4],
              [-3, 0, 6, 0, -3],
              [-1, -3, -4, -3, -1]])
highpass_3x3 = ndimage.convolve(data, kernel)
```

```
plot(highpass_3x3, 'Laplace High Pass Filter (5x5)')

kernel2 = np.array([[-1, 0, 1],
              [-1,  0,  1],
              [-1,  0,  1]])
highpass_5x5 = ndimage.convolve(data, kernel2)
plot(highpass_5x5, 'Prewitt Gradient Filter (vertical)')

kernel2 = np.array([[1, 1, 1],
              [0,  0,  0],
              [-1, - 1,  -1]])
highpass_5x5 = ndimage.convolve(data, kernel2)
plot(highpass_5x5, 'Prewitt Gradient Filter (horizontal)')

kernel2 = np.array([[-1, 0, 1],
              [-2,  0,  2],
              [-1,  0,  1]])
highpass_5x5 = ndimage.convolve(data, kernel2)
plot(highpass_5x5, 'Sobel Gradient Filter (vertical)')

kernel2 = np.array([[1, 2, 1],
              [0,  0,  0],
              [-1, -2,  -1]])
highpass_5x5 = ndimage.convolve(data, kernel2)
plot(highpass_5x5, 'Sobel Gradient Filter (horizontal)')

plt.show()
```

МЕТОД ПОКРАЩЕННЯ КОСМОЗНІМКІВ З ВИКОРИСТАННЯМ ПРОСТОРОВИХ ОПТИЧНИХ МАСОК ТА ЧАСТОТНИХ ФІЛЬТРІВ.

І. Половинко, А. Кашуба

Львівський національний університет імені Івана Франка
вул. Драгоманова, 50, 79005, Львів, Україна
polovynkoi@gmail.com , AndriyKashuba07@gmail.com

У роботі запропоновано простий ефективний метод покращення якості космознімків, який базується на просторовій і частотній фільтрації зображень з використанням різноманітних фільтрів. Метод базується на теорії створення оптичних масок з використанням теореми згортки з наступним здійсненням частотної фільтрації. Роботу такого методу продемонстровано на прикладі гаусівського згладжуючого фільтру. Практична частина роботи реалізована із використанням мови програмування Python 3.7.4 у середовищі розробки Visual Studio 2017 Community Edition а також із використанням Jupyter Nonebook. Розроблено різноманітниы просторовы фільтри-маски а також створено гаусівські високо- та низькочастотні фільтри. Властивостями останніх можна керувати

шляхом зміни параметру ширини гаусівської кривої σ. Реалізацію можливостей фільтрів продемонстровано на космознімку залишків оборонного монастиря Св. Василія Великого. Аналіз впливу фільтрів на зображення показав, що кожен з них здійснює певну дію. Для сприйняття за допомогою людського ока найбільш помітний вплив здійснюють низькочастотні згладжуючі фільтри. Це в першу чергу пов'язане із тим , що при такій фільтрації значення яскравості окремого пікселя замінюється середнім значенням у градаціях сірого при використанні відповідної маски. При цьому на зображенні зменшуються різкі переходи на рівні сірого. Оскільки усереднений шум проявляється у різких переходах , то слід очікувати що згладжування приведе до зменшення шумів. Однак краї, які завжди присутні на зображеннях, також характеризуються різкими переходами на рівнях сірого. Тому використання усереднюючих фільтрів дає небажаний ефект у розмитті країв. Усунути такий недолік дозволило використання гаусівських високочастотних і низькочастотних фільтрів, у яких можна змінювати ширину гаусівської кривої σ. Зокрема було показано, що у випадку високочастотних фільтрів більш різко проявляються контури оборонних мурів ($\sigma = 12$). Натомість при використанні низькочастотних згладжуючих фільтрів краще проглядаються певні плавні просторові області. Так при ($\sigma = 24$) появляються залишки оборонних споруд ,які не проглядаються ні на оригіналі.

Аналіз космознімків також показав, що на них також спостерігаються адитивні шуми, які на вдається усунути шляхом частотної або просторової фільтрації. Такі шуми , як правило виникають в процесі самої зйомки їч можна позбутись методами відновлення зображень.

У роботі також представлена написана на мові Python 3.7.4 оригінальна програма, із використанням внутрішніх функцій ,яка дозволяє створювати просторові маски вищих порядків.

Отримані результати можуть бути корисні при створенні елементів комп'ютерного зору.

Ключові слова: функція Гауса,теорема згортки, космознімки, оптичні маски, гаусівські високочастотні і низькочастотні просторові фільтри

Стаття: надійшла до редакції 27.09.2019,
доопрацьована 02.10.2019,
прийнята до друку 04.10.2019.