13

Computer image processing

This chapter focuses on a preparation of our broadcast contents – image and photo editing before the transmission.

There are available many programs for image editing, from complex editors for bitmap images to simple viewers with few editing functions. Some SSTV programs have also image editing functions.

The selection of suitable program depends on a user and his needs and although a control of programs can be slightly different the procedures described later are so general that it would not be a problem to achieve results using your favorite editor. The appropriate editor is generally any program for editing of raster/bitmap images, such as: GIMP, Paint Shop Pro, Adobe Photoshop, Pixel32,... Less suitable are vector image editors, such as: Corel Draw!, Inkscape, etc.

There are described some basic principles and functions, which are used in most common programs. Although some functions below are shown in GIMP, see sec. **??**, it should not be problem for savvy user to find same functions in his favourite editor.

Later, see section **??**, there are specific tutorials only for GIMP.

13.1 Image resizing

The SSTV uses a relative small resolution in comparison with images you can get from digital cameras, scanners or some internet galleries. So before transmission the image should be resized to conventional resolution 320×240 pixels. You can achieve this in almost all SSTV programs, but images sometimes haven't aspect ratio $4:3$ or we want use only part of image. So it is useful to prepare your images before QSO.

The image resizing brings a little risk, see **image 13.1**, original image is test chart on page **??**.
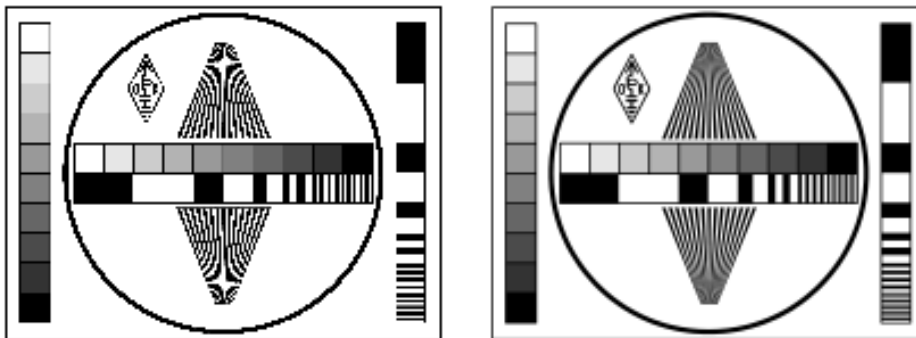
Figure 13.1: Results of image
resizing with two different algorithms.

There is a result of two image scaling algorithms. The left image was scaled down by *nearest-neighbor interpolation*, when pixels in regular columns and rows are removed. But the *linear interpolation* was used for the right image. The difference is visible on the first sight, the nearest-neighbor method caused distortion and some details are lost completely, e.g. thin lines are lost and on originally smooth curves are stair-like lines more evident. The linear interpolation is more considerate to details, but it depends on amount of decreasing and sometimes there should arise a *moiré*, here on the raster of changing white and black stripes.

Almost every image editing software give an option for used scaling method, so choose linear interpolation (or bilinear or bicubic). A raster image for interpolation must have at least 16bit color depth, on indexed images with 256 or less colors it doesn't work, but you can convert them to more colors temporary and then back.

13.2 Color adjustment

Basic tools for the color adjustment can edit image contrast, brightness, color saturation and hue. The advanced tools are *curves adjustment* and *image histogram*.

The histogram is a representation of the distributions of colors in an image (see **pic. 13.2**). It is bar graph and there is representation of the tonal variations on the horizontal axis and the vertical axis represents the number of pixel in the particular tone.

In digital photography, you can easily review exposure by histogram. If the image is underexposed the amount of darker pixels lays on left side of graph (more darker pixels), vice-versa for overexposed images there is high number of lighter pixels on right side. It is possible to check exposure in the digital camera menu and take snapshot again, of course unless the image wasn't dark or light in principle.

The ideal case is if the luminance is wide-spread inside the luminance range. For low contrast the luminance values are spread only over smaller range of luminace.
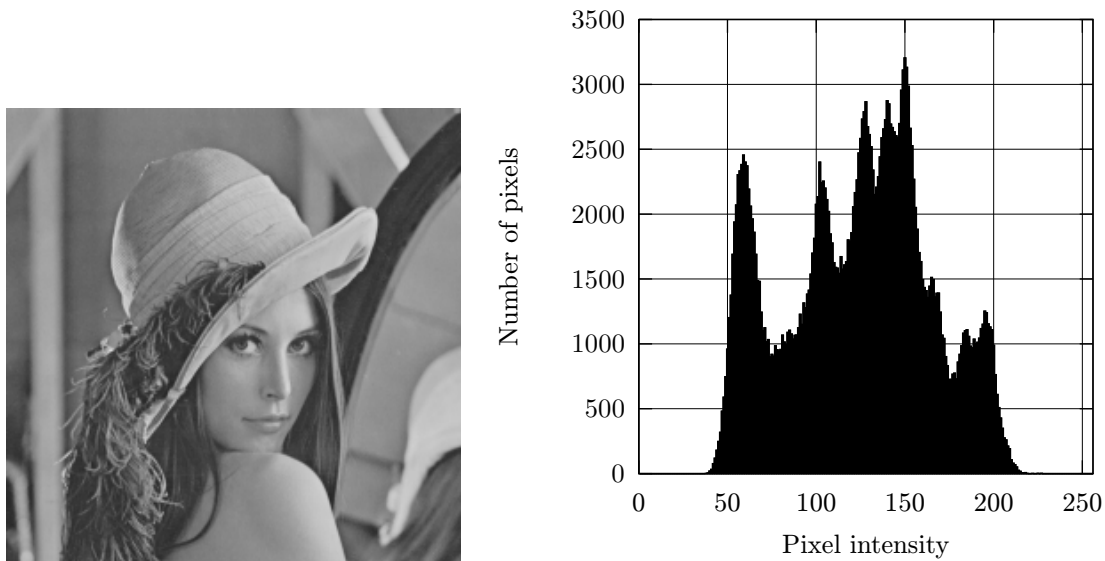
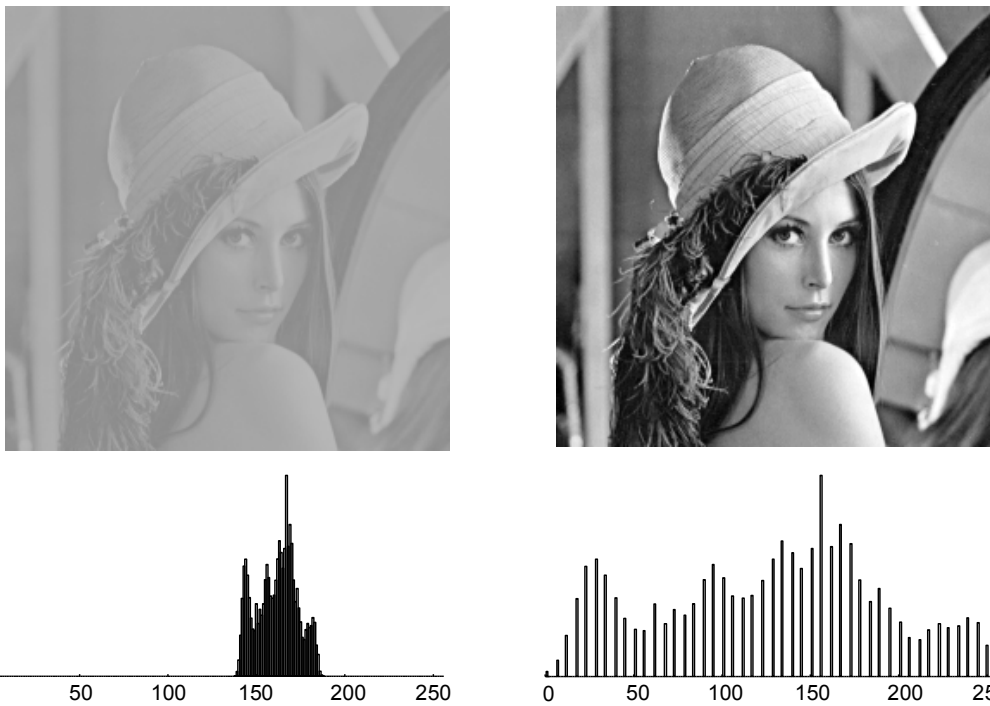**Figure 13.2:**   The image histogram for 256 brigtness values.

Figure 13.3:   Positive influence of
histogram equalization on image contrast.

The histogram *equalization* can help to adjust contrast of image – luminace is spread
over all range. For the result of histogram equalization see **pic. 13.3**.

In the GIMP the tool for histogram adjustment is in menu *Colors → Levels.* In case of low contrast image in **pic. 13.3** the input levels were set on edges of growing values, but the GIMP can make also automatic equalization with **dialog 13.4**.
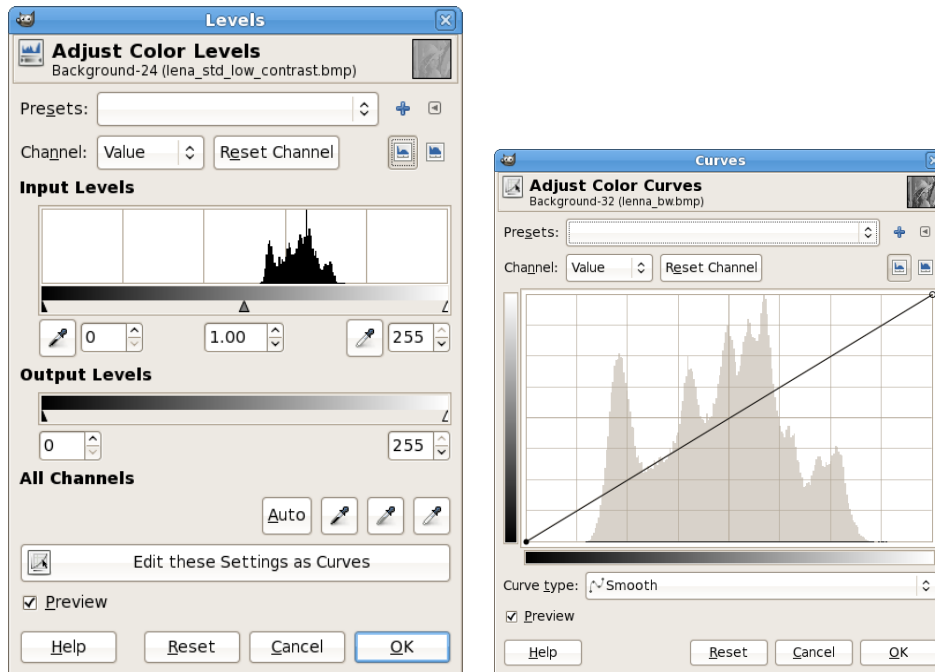

Figure 13.4:

The second important tool is curve adjustment, its the one of most important tools in professional graphics editors. It provides the complex settings of color tone, brightness and contrast. The GIMP tool *Adjust Color Curves* (**pic. 13.4**) is in menu *Colors → Curves.* Its functionality is very similar across image editing software.

The work with curves is quite simple. The tool window has on the x axis displayed input luminance values and on the y axis output values, which are presented as gray-scale. The curve self is the function $y = f(x)$ and it transforms input values to output and by its shaping the user sets the parameters of the transformation.

At the beginning the transformation function is $y = x$ and therefore the output level is equal to input. When you touch the curve by cursor a control point appears on the curve. You can move this point in every direction and if the option *Preview* is switched on, then the results will be shown immediately. It is possible to add more control points for continuous transformation or you can set any curve shape with discontinuous transformation.

What you can do with it? The results of transformations and the used curves is in **pic. 13.5**. You can spread input values by histogram and improve contrast – **13.5**A.

Another use is to darken or lighten the image, but there is many more options how to do this then a simple setting of levels. With the curve you can focus on a

range of colors, can edit only midrange portion of color scale and keep black and light pixels, if you hold curve in the middle and move the control point upwards and if you move the point more to the left or right you can change brightness of darker or lighter tones. In **example 13.5**B are lighter tones made more brighter and the lower end of curve is moved to the right, so darker pixel are more darker and the image is more contrasted. For image darkening move the point downwards, it's in **example 13.5**C, also there is moved the right edge of the curve so lighter pixel are more brighter now.

For changing contrast use the curve in **13.5**D, there are two control points. The curve with "S" shape makes dark tones darker and light tones brighter.

In addition to basic editing the curve can be used for a variety of effects, see **example 13.5**. The shape is little crazy and result image lost real tones. Notice, that there is inversion of dark tones in left part of the curve.

The curve and histogram adjustment is possible to do for image luminance and for each color component too, so it is possible to change color perception of an image.

13.3 Filters

Images can be further improved using various filters. They can serve different purposes, mainly for smoothing and noise reduction, increasing sharpness, edge detection, unsharp masking, etc.

Digital image itself is a discrete two-dimensional (2D) signal, which is characterized by its frequency spectrum, whose components similar to the 1D signal can be determined using the discrete Fourier transform. So it's possible to modify image by using low or high pass filters or highlight certain components to affect the final look.

For specific case, we can return to chapter **??** (page **??**), there is described how the SSTV transmission is affected by bandwidth. The limited bandwidth caused the distortion of fine grid in resolution test pattern (pic. **??**). Fine grid and sharp gradients in the image represent a high frequency components and limited bandwidth acted as a bandpass filter, which suppressed the higher frequencies. Also, an image noise is represented by high frequency components and the low-pass filter can be used for its reduction. Vice-versa, a high-pass filter is designed to highlight the edges and sharpening.

13.3.1 Convolution matrix

As one of the methods of linear filters is used the higher mathematic procedure – *discrete convolution*. A way the image is processed is given by *convolution kernel*, which is given by matrix, typically with dimensions 3×3 or 5×5, but also others.
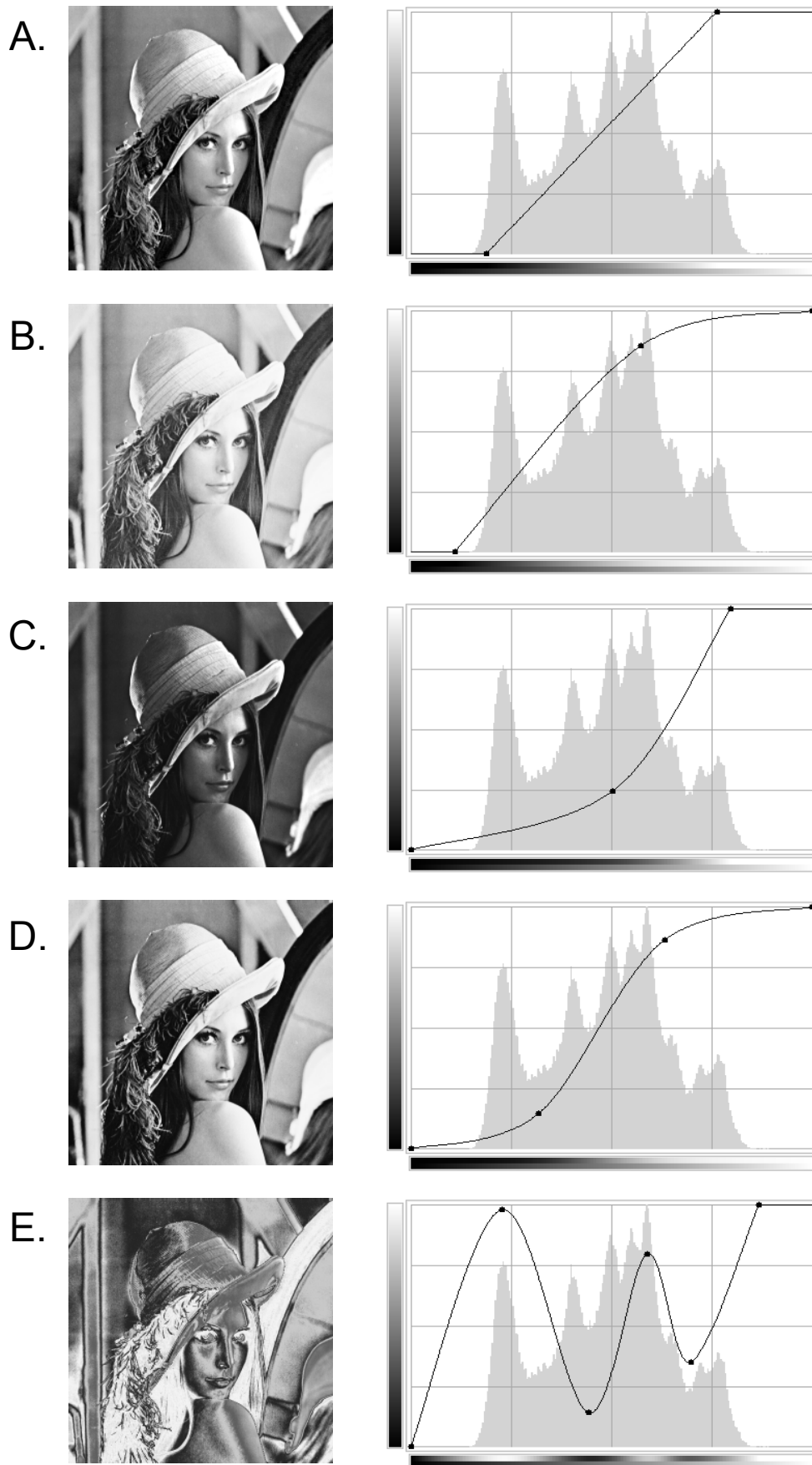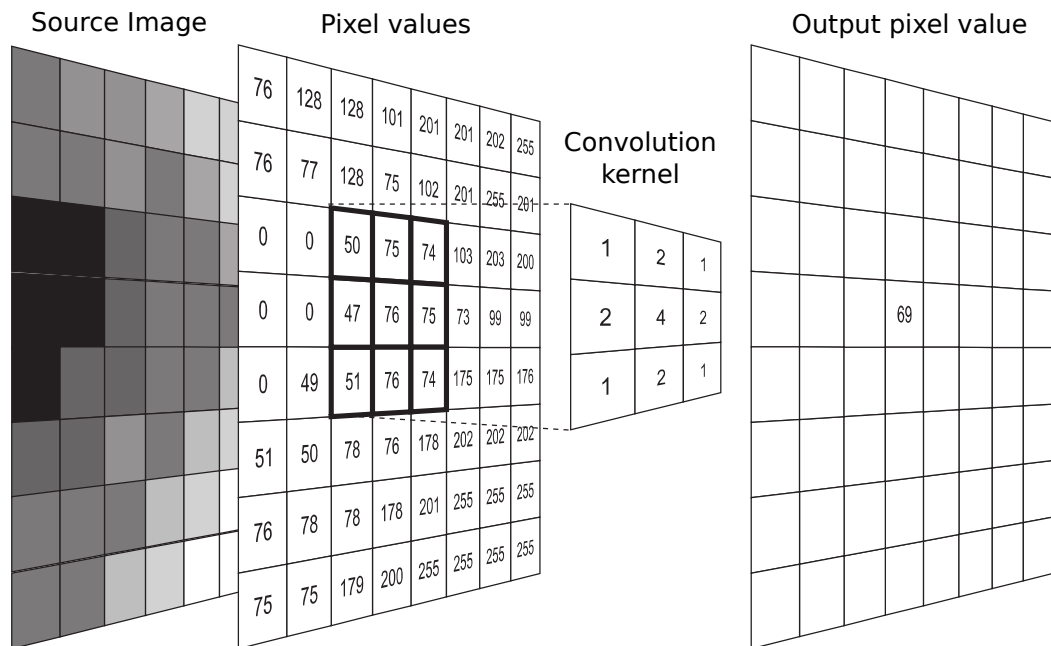
Figure 13.6:   Computation of discrete convolution.

The kernel moves pixel by pixel along lines and columns of the source image and computes pixel values, see **fig. 13.6**. It moves from first pixel on the position 0,0, then 0,1, etc. For each pixel is from neighborhood pixels (their numerical luminance values) multiplied by kernel values, added together and resulting value is stored in target image on same position as source. Then the matrix moves to next pixel and computation is repeated.

The target image changes in way defined by values of convolution kernel, e.g. matrix $\mathbf{H_2}$ in **fig. 13.6** use pixel and its neighborhood of 3×3 size and computes weighted mean from these nine pixel with kernel:

$$\mathbf{H_2} = \frac{\mathbf{1}}{\mathbf{16}} \begin{pmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{pmatrix}, \qquad \begin{array}{l} \frac{1}{16}(1 \cdot 50 + 2 \cdot 75 + 1 \cdot 74 + \\ \quad + 2 \cdot 47 + 4 \cdot 76 + 2 \cdot 75 + \\ \quad + 1 \cdot 51 + 2 \cdot 76 + 1 \cdot 74) \end{array} = \mathbf{69}$$

The result is an image smoothing and noise reduction. Other matrices are used to increase sharpness, edge detection or to create a relief.

In the GIMP the filter is in menu *Filters → Generic → Convolution Matrix.* The important parameters are also *divisor*, which adjusts the values in the matrix and *offse* is used to adjust the colors. See **fig. 13.7**, how to set matrix values and parameters. Furthermore you can choose the color channels and behaviour of

calculation on border pixels, it is also possible to determine the divisor and offset automatically.
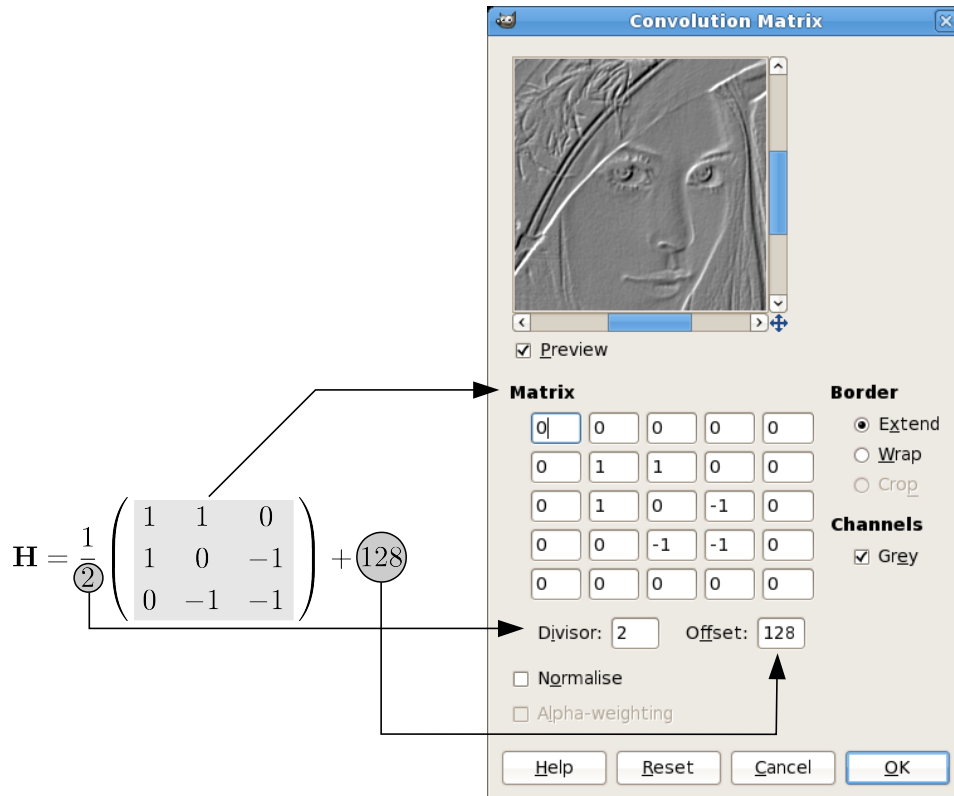

$$\mathbf{H} = \frac{1}{2} \begin{pmatrix} 1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -1 \end{pmatrix} + 128$$

Figure 13.7: Convolution matrix parameters in GIMP.

13.3.2 Noise reduction

Thanks to noise reduction it is possible to improve partially received SSTV or WEFAX images by smoothing. It can be done several ways. Since SSTV transmission takes a relatively long time the noise levels are often uneven, affected by random interference and transmission conditions, so you can by tool *Selection* mark affected areas, where apply the filter.

13.3.2.1 Spatial average filtering

The simplest way to reduce noise is *average filter* with convolution kernel $\mathbf{H_1}$.

$$\mathbf{H_1} = \frac{1}{9} \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

The next useful matrices for averaging are $\mathbf{H_2}$ and $\mathbf{H_3}$, they aren't using neighbor pixel with same weight, but near pixels have greater coefficients then farther. The values of the coefficients are based on binomial series.

$$\mathbf{H_2} = \frac{1}{16} \begin{pmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{pmatrix} \qquad \mathbf{H_3} = \frac{1}{256} \begin{pmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix}$$

The disadvantage of averaging filters is that smoothing distorts sharp color gradients and due to it thin lines and other details are distorted.

Received image   Averaging $\mathbf{H_1}$

Binom. filter $3 \times 3 \mathbf{H_2}$ Binom. filter $5 \times 5 \mathbf{H_3}$

Figure 13.8:

Next filters for noise reduction in GIMP are in menu *Filters → Blur →....* E.g. *Gaussian blur* is useful for SSTV noise reduction, the user can set a radius of a blur. For image preparation can be used *Selective Gaussian Blur*, it can filter continuous areas and edges leaves unaffected, but for received images is not suitable.

13.3.2.2 Median filter

The term *median* is the middle value in list of numbers, here luminance values. The image filter works with pixel neighborhood, e.g. with 3×3 size, then sort their values and takes the median, i.e. middle value of the sequence:

21	22	20	**Pixels:** 21, 22, 20, 21, 19, 231, 19, 21, 20	
21	19	231	**Sorted:** 19, 19, 20, 20, <u>21</u>, 21, 21, 22, 231	
19	21	20	**Average** $\doteq 43$; **Median** $= 21$	

Table 13.1: none

We see that if we use the averaging, then significantly skewed value 231, which can be caused by noise, greatly affects the result. In contrast, the median is not influenced by extreme deviations. The disadvantage of median filtering is that it sometimes distorts the thin lines and sharp gradient in the image.

Received image

Binom. filter $\mathbf{H_2}$

Median 3×3

Median 5×5

Figure 13.9: The results of noise reduction with median filter.

In GIMP the median filter is in *Filters → Enhance → Despeckle*. There are several options for filter settings. The radius from 1 for 3×3 neighborhood to 20 for 41×41

and the black level (-1–255) and white (0–256). The pixels darker or brighter than these two levels will be removed, filter passes every level for the extreme values -1 and 256. Moreover, it is still possible to select *adaptive* median, when GIMP tries to determine optimal radius for given image location automatically (the user parameters are ignored).

13.3.3 Sharpening

Often happens that images from cameras or scanners have reduced sharp edges. In this case you can try to use sharpening filters, for edges highlighting. There are two convolution kernels for sharpening $\mathbf{H_4}$ and $\mathbf{H_5}$ with an even stronger effect.

$$\mathbf{H_4} = \begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix} \qquad \mathbf{H_5} = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix}$$

In the GIMP the sharpening filters are in the menu *Filters → Enhance →....* The first one is *Sharpen*, and it has similar results as kernels above and it is possible to set sharpening level and from preview select the best results.

The disadvantage of these filters is that, it also highlights the image noise and some other unwanted details. It can be seen in **fig. 13.10** when the filter $\mathbf{H_5}$ is used, so there appears teeth on vertical edges caused by camera interlacing. In this case it's possible to use filter called *unsharp mask*. The unsharp mask procedure in first step apply Gaussian blur on image copy and then check the difference between blurred and original image. When the difference is greater then a user-defined threshold, then both images are subtracted and the result is added to original image. The threshold limits the sharpness of output image, so small details of certain size is not sharpened. Thanks to this the sharpening does not apply to noise and graininess. The digital unsharp mask is great filter for enhancing sharpness. Some results are influenced by these three parameters:

▷ *Amount* indicates how much will increase the contrast of edges, by the edge lightens or darkens, this setting will affect most the degree of sharpening.
▷ *Radius* sets how much pixels around edges will be used. For smaller radius the filter affect also smaller details, but for greater it may produce a bright rim around edges.
▷ *Threshold* controls the minimum brightness change that will be sharpened. Thanks to threshold it is possible to enhance only stronger edges and finer leave unchanged.

No wonder, that unsharp mask is considered as king in improving the image. The only drawback is that if you blow over it, then around edges occurs distinctive bright rim and the image looks unnaturally.

Original image
from CCD camera

Sharpening $\mathbf{H_4}$

Sharpening $\mathbf{H_5}$

radius: 2.5; amount:
1.5; threshold: 0

Figure 13.10: Results of image sharpening.