Methods of Digital Filtration and Their Impacts on the Quality of Images of Different Classes

Introduction

There is almost no area in the technology that would not have to deal with digital imaging (DI) processing to a greater or lesser extent. One of the methods of processing a central filter is filtration. In this case, filtration in most cases is not the final stage of processing, but serves as some preliminary form, for example, for further identification of images, improvement of visual perception, or embedding or removal of steganographic containers [1; 2].

Main part

The aim of the work is to analyze the methods and characteristics of frequency filtration of digital images of different classes, as well as to establish the functional dependence of the degree of distortion of a digital image, depending on the image class, separately for each component of the RGB color model.

The main methods of processing the DI are digital filters. Filters can be linear or nonlinear. The filtration processes consist in the transformation of the components or parameters of the CP that have the result of obtaining images of the same size as the original, converted according to certain rules, in order to improve the quality of the image, the allocation of special zones, and so on.

A filter is called linear if the function that it assigns meets two conditions of linearity: additives — the condition where the result of applying this function to the sum of the two input images and coincides with the sum of the results of the application of such a function to these images separately, and the homogeneity — a condition that requires preservation of uniqueness of scale at transformation input digital image

\[ F[A(x, y) + B(x, y)] = F[A(x, y)] + F[B(x, y)]; \]

\[ F[cA(x, y)] = cF[A(x, y)], \]

where \( c \) — the scale; \( A(x, y) \) — input DI.

If the conditions of additives and homogeneity are not satisfied, the filter is called nonlinear.

All methods of filtration can be divided into: spatial, frequency and combined (spatial-frequency) methods of processing the DI [3].

Spatial methods combine approaches based on manipulations with pixels of the DI. The image after filtering \( C(x, y) \) is obtained using a convolution formula, where \( K_{ij} \) — the filter coefficients, \( A(x, y) \) — the input DI.

\[
C(x, y) = K_1A(x - 1, y - 1) + K_2A(x - 1, y) + K_3A(x - 1, y + 1) + K_4A(x, y - 1) + K_5A(x, y) + K_6A(x, y + 1) + K_7A(x + 1, y - 1) + K_8A(x + 1, y) + K_9A(x + 1, y + 1).\]

Typical low-frequency (LF) and high-frequency (HF) spatial masks filtration and the results of their use are presented on Fig. 1.

Frequency methods are based on the modification of the signal, which is formed by using the Fourier transform to the DI. With the Fourier transform, the DI is transmitted from the spatial domain to the frequency. At the same time, the low frequencies are
We use frequency filtering to the DI. At the same time, by changing the size of the filter and moving it in the frequency domain, we can highlight the “low” frequencies that are responsible for the main content of the image — the background and large-sized objects, or “high” frequencies, that is, distinguish the minor features of the image, objects small size, small parts of large shapes. The block diagram of the implementation of frequency filtration for the DI is shown in Fig. 2.

In order to more accurately evaluate the effect of the frequency filtering operation on the CZ, the concept of a class of images needs to be introduced. Conditionally divide digital images into classes. The filter that lowers the low frequencies while simultaneously skipping high — high-frequency filter.

The filtration process is determined by the formula:

\[ B(x, y) = \sum_i \sum_j F(i, j) \cdot A(x + i, y + j), \]

where \( A(x, y) \) — digital image; \( i, j \) — dimension filter; \( F(i, j) \) — filter function; \( B(x, y) \) — filtered DI.

Most methods of steganography provide low robustness to any distortion. For example, applying a loss-condensation operation leads to the complete destruction of the embedded message in the spatial area. More robust to a variety of distortions are the methods of steganographic protection of information used to conceal the data frequency domain [4].

Any image can be interpreted through a set of pixel-organized matrices, the colour vector \( A(x, y) \) for each pixel of the image, where the color value defines a three-component vector in the colour space, using the colour RGB model. To implement frequency filtering, we will decompose the DI in the RGB model. We translate the received matrix representation by means of a direct Fourier transform into the frequency domain.

After translating an image using a direct Fourier transform into the frequency spectrum, the rough clear lines of the image concentrate closer to zero — high peaks of the spectrum, and the semitone and shades of the image are further down the surface.

Using this property, we filter high, low and medium frequencies images by filters of different sizes. The filtering process is based on the simple movement of the filter mask over the frequency spectrum of the image, cording to the informal definition of CE classes by compression algorithm [5].

Class 1. Images with a small number of colors (4–16) and large areas filled with the same color. There are no smooth transitions of colors.

Class 2. Images with smooth color transitions built on a computer.

Class 3. Photorealistic images.

Class 4. Photorealistic images with overlay business graphics.

It was found that the characteristic difference between the DI of different classes is the laws of the distribution of the values of the brightness of the neighboring pixels.

The matrices of pixel intensity for images of different classes are shown in Fig. 3. So for the 1st class is characterized by the presence of large areas with the same values of the intensity of the pixels. For the 2nd class, the values of neighboring pixels can be any, because the image was created using a computer. For the 3rd class, which includes scanned realistic images (color and grayscale), pixel values change smoothly, there can be no sharp difference between adjacent pixels. If a realistic image is made using software, for example special effects are applied, then the distribution of pixel intensity varies. In the middle of the same values we can detect pixels with a sharp change in values. Such images belong to the 4th class.

\[ \sum \sum \]
Fig. 2. The block diagram of the implementation of frequency filtration for digital image
Frequency filtration is performed for the DI of all the above classes, each colour component separately, to establish the functional dependence of the degree of distortion of the digital image, depending on the change of the class of the digital image, separately for each component of the colour model. All images are in bmp format that has resolution 128 x 128. The size of the filter window will be determined as 64 x 64 for all classes of images. The image frequency filtering performs smoothing with low-frequency filtration (LF), and the selection of contours and small-sized objects by means of high-frequency filtration (HF). Frequency filtration results for different classes of DI are presented in Fig. 4.

The visual analysis of the results is as follows. With a sufficiently small window of the low-pass filter, additive interferences are suppressed, but the contours of the image are very blurred. High-frequency component of the image ceases to be informative, since there is now completely present and noise component.

![LF filtration](image1.png)

![HF filtration](image2.png)
If we evaluate the quality of the filtering from an objective point of view, we must use the existing features to evaluate the degree of distortion of the digital image. Most of the distortion indicators or quality criteria used for visual processing of information are based on the differences between the initial digital image and the image obtained after the distortion.

To analyze image distortion after filtering, we use the most commonly used PSNR (Peak signal-to-noise ratio) — peak signal to noise ratio, which is most often used to measure distortion levels when compressing images. PSNR is calculated by the formula

\[
PSNR = 10 \log_{10} \left( \frac{MAX_i^2}{MSE} \right) = 20 \log_{10} \left( \frac{MAX_i}{\sqrt{MSE}} \right),
\]

where \( MAX_i \) — the maximum pixel value of the image, in our case at a bit size of 8 bits \( MAX_i = 255 \); \( MSE \) — square root error for images \( I(i, j) \) and \( K(i, j) \) the size of \( m \times n \), is determined by the formula

\[
MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} |I(i, j) - K(i, j)|^2
\]

The results of the study are presented in Table 1, Table 2 and Fig. 5.

### Table 1

<table>
<thead>
<tr>
<th>PSNR after using HF filtration</th>
<th>1 class (%)</th>
<th>2 class (%)</th>
<th>3 class (%)</th>
<th>4 class (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGB</td>
<td>16.771</td>
<td>53.489</td>
<td>16.321</td>
<td>53.264</td>
</tr>
<tr>
<td>R</td>
<td>17.97</td>
<td>54.088</td>
<td>17.90</td>
<td>54.053</td>
</tr>
<tr>
<td>G</td>
<td>20.281</td>
<td>55.21</td>
<td>16.966</td>
<td>53.552</td>
</tr>
<tr>
<td>B</td>
<td>21.205</td>
<td>55.706</td>
<td>18.064</td>
<td>54.135</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>PSNR after using LF filtration</th>
<th>1 class (%)</th>
<th>2 class (%)</th>
<th>3 class (%)</th>
<th>4 class (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGB</td>
<td>0.598</td>
<td>45.402</td>
<td>10.519</td>
<td>50.363</td>
</tr>
<tr>
<td>R</td>
<td>0.366</td>
<td>45.287</td>
<td>9.741</td>
<td>49.974</td>
</tr>
<tr>
<td>G</td>
<td>0.376</td>
<td>45.257</td>
<td>7.571</td>
<td>48.855</td>
</tr>
<tr>
<td>B</td>
<td>0.287</td>
<td>45.247</td>
<td>9.285</td>
<td>49.746</td>
</tr>
</tbody>
</table>

### Fig. 5

Value Diagrams PSNR: \( a \) — HF filtration; \( b \) — LF filtration.

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From the data obtained, we can conclude that the values of the PSNR characteristics are different for different color components of the image.

As a result of using an HF filter, the least distortion is found in the red component for the first class, in green for the second class, and in blue for the third and fourth class.

As a result of using a low pass filter, the least distortion was found in the red component for the third and fourth classes in green for the 2nd class, and in blue for the 1st class.

Realistic images taken with a digital camera (class 3) are of greater interest in terms of using as efficient containers in steganography. Due to the even distribution of the intensity of the pixels and increase the noise level when scanning, the detection of hidden content is a much higher complexity.

**Conclusion**

Different methods of filtration and digital image classes are investigated in this work. The frequency filtering method for digital imaging was implemented and the degree of PSNR distortion of a digital image was investigated, depending on the image class, separately for each component of the RGB colour model.

An algorithm for removing segments of the spectrum of three colour gamut is proposed and it is proved that the functional dependences of distortion of quality of digital images of different classes are different for the red, green and blue components of the color model. The specified statistics may be the basis for further research to develop modern effective methods of steganography and steganalysis from the condition of embedding containers into different colour components.

**LITERATURE**

4. Lukichov V. V. Methods and means of steganographic information protection in. — 76 с.
METODS OF DIGITAL FILTRATION AND THEIR IMPACTS ON THE QUALITY OF IMAGES OF DIFFERENT CLASSES

Different methods of filtration and digital imaging classes have been analyzed and investigated. The frequency filtering method for digital imaging was implemented and the degree of distortion of the digital image was investigated, depending on the image class, separately for each component of the RGB color model. In the study of digital static images of different classes, methods of frequency filtration are used. The procedure for removing the segments of the spectrum of three color gamut is obtained. The indicated statistics may be the basis for further research for the development of modern effective methods of steganography and steganalization.

Keywords: methods of frequency filtration, spatial filtration methods, digital image, steganography, digital image distortion measure.