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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 a 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 $K_{i,j}$ — 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 responsible for clear features of the DI, contours, and high frequencies — for the half-tones and the fuzzy features of the DI. After application of the filter to the DI spectrum, the inverse Fourier transform is performed and at the output we receive a filtered DI. The filter that weakenshigh frequencies, while missing low is called low frequency filter.

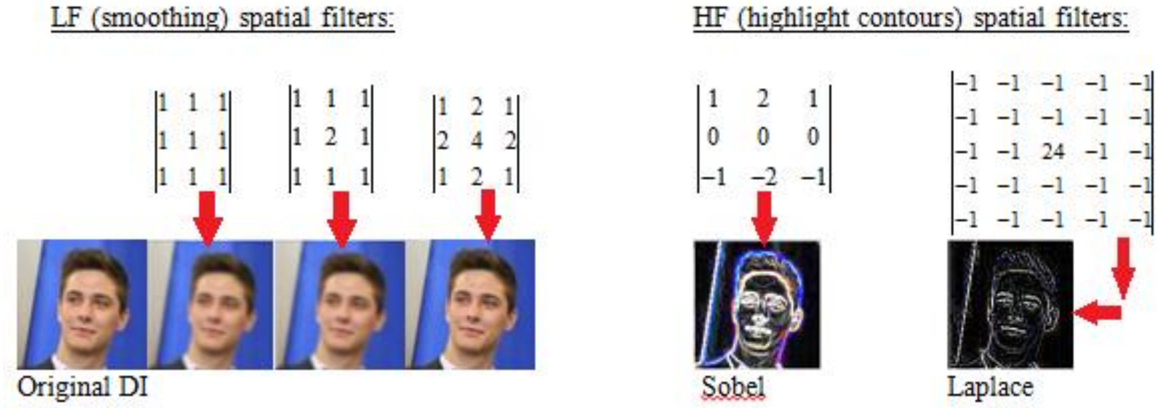


Fig. 1. LF and HF spatial masks filtration and the results of their use

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:

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

де $A(x,y)$ — 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 izes. 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.

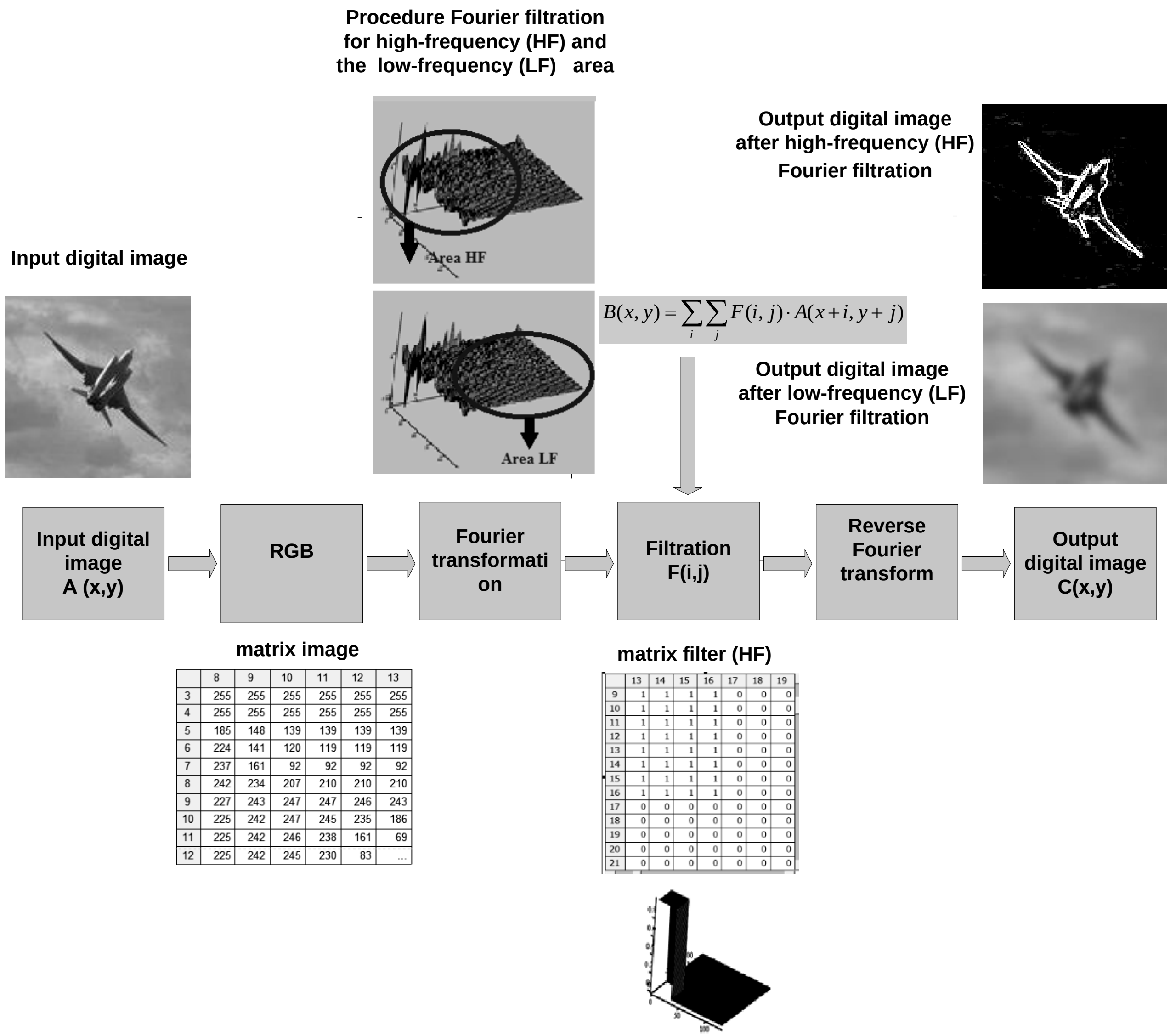
Class 2. Images with smooth color transitions built on a computer.

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 matrixes 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.



matrix image

	8	9	10	11	12	13
3	255	255	255	255	255	255
4	255	255	255	255	255	255
5	185	148	139	139	139	139
6	224	141	120	119	119	119
7	237	161	92	92	92	92
8	242	234	207	210	210	210
9	227	243	247	247	246	243
10	225	242	247	245	235	186
11	225	242	246	238	161	69
12	225	242	245	230	83	...

matrix filter (HF)

	13	14	15	16	17	18	19
9	1	1	1	1	0	0	0
10	1	1	1	1	0	0	0
11	1	1	1	1	0	0	0
12	1	1	1	1	0	0	0
13	1	1	1	1	0	0	0
14	1	1	1	1	0	0	0
15	1	1	1	1	0	0	0
16	1	1	1	1	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0

Fig. 2. The block diagram of the implementation of frequency filtration for digital image

	96	97	98	99	100	101	102	103	104	105
31	224	224	224	224	234	153	8	246	228	224
32	255	255	255	255	255	58	114	255	255	255
33	255	255	255	255	244	0	232	255	255	255
34	255	255	255	255	132	38	255	255	255	255
35	255	255	255	255	18	159	255	255	255	255
36	255	255	255	206	0	255	255	255	255	255
37	255	255	255	89	82	255	255	255	255	255
38	255	255	255	0	201	255	255	255	255	255
39	255	255	164	14	255	255	255	255	255	255
40	255	255	45	126	255	255	255	255	255	255
41	255	237	0	238	255	255	255	255	255	255
42	255	121	49	255	255	255	255	255	255	255
43	255	4	171	255	255	255	255	255	255	255
44	194	0	255	255	255	255	255	255	255	255
45	75	95	255	255	255	255	255	255	255	255
46	0	213	255	255	255	255	255	255	255	...

Class 1

	76	77	78	79	80	81	82	83	84	85
40	91	113	130	137	154	163	171	153	157	164
41	82	98	117	127	138	151	152	158	161	170
42	75	84	99	122	134	143	142	158	132	165
43	74	82	102	117	130	137	154	158	141	118
44	73	84	101	109	121	156	165	175	190	162
45	63	76	90	109	122	135	151	164	183	203
46	62	73	89	94	111	130	146	167	183	200
47	60	72	80	94	115	118	136	169	177	198
48	60	71	83	99	118	112	125	157	172	195
49	58	69	87	97	112	118	123	140	164	181
50	58	69	76	92	106	118	127	136	156	168
51	58	66	72	90	97	108	123	134	150	164
52	59	59	70	87	96	105	115	125	149	159
53	56	58	67	85	97	105	112	123	141	157
54	53	62	69	86	95	102	114	126	133	148
55	52	65	72	88	93	99	117	128	125	138

Class 2

	58	59	60	61	62	63	64
28	109	108	103	100	96	95	98
29	107	105	102	101	100	101	103
30	103	101	102	103	105	107	109
31	101	100	101	104	107	110	111
32	101	100	101	103	106	109	109
33	102	101	101	103	105	106	107
34	102	102	102	103	105	105	106
35	102	102	102	104	106	106	106
36	104	104	106	103	100	100	103
37	101	100	101	101	102	104	105
38	98	97	100	102	103	103	100
39	98	96	95	97	100	103	...

Class 3

	45	46	47	48	49	50	51
28	123	168	171	110	210	230	241
29	146	162	188	139	208	227	242
30	189	200	211	161	218	191	220
31	233	41	248	130	204	190	217
32	230	164	200	16	16	97	79
33	226	236	11	0	0	0	0
34	243	88	0	0	0	0	0
35	69	0	0	0	0	1	0
36	0	0	0	0	0	0	1
37	0	0	0	0	1	0	2
38	0	0	0	0	0	0	0
39	0	1	1	0	1	0	...

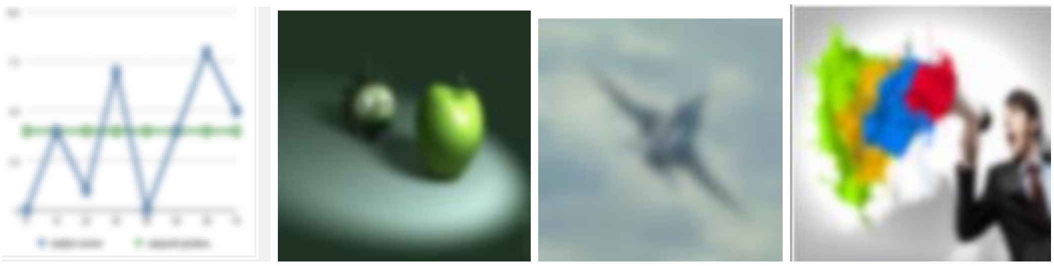
Class 4

Fig. 3. Matrixs of pixel intensities for images of different classes

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 128×128. The size of the filter window will be determined as 64×64 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



1 class 2 class 3 class 4 class

HF filtration

1 class 2 class 3 class 4 class

Рис. 4. LF filtration and HF filtration for digital imaging of different classes

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

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

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

Table 1

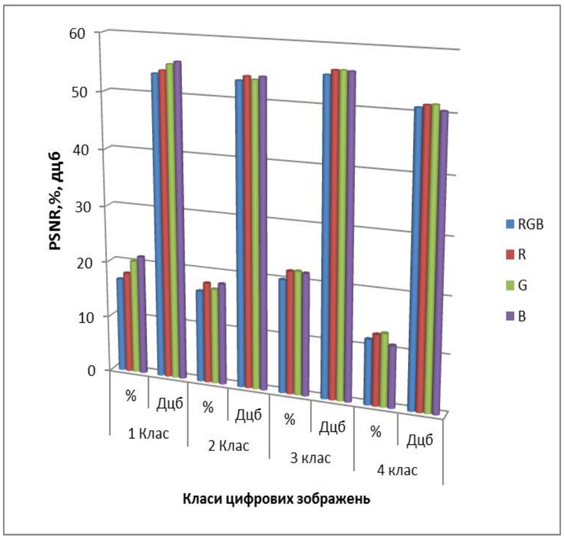
PSNR after using HF filtration

PSNR т								
	1 class		2 class		3 class		4 class	
	%	dB	%	dB	%	dB	%	dB
RGB	16.771	53.489	16.321	53.264	20.099	55.153	11.566	50.887
R	17.97	54.088	17.90	54.053	21.755	55.981	12.568	51.388
G	20.281	55.21	16.966	53.552	21.883	56.011	12.934	51.537
B	21.205	55.706	18.064	54.135	21.666	55.937	10.995	50.601

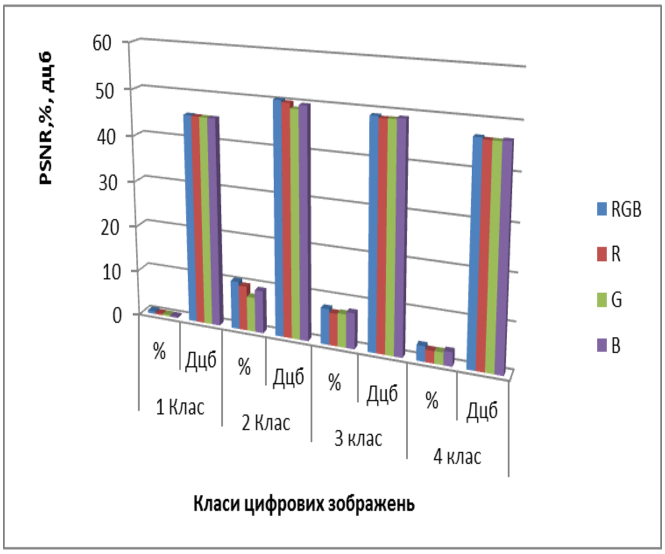
Table 2

PSNR after using LF filtration

PSNR								
	1 class		2 class c		3 class		4 class	
	%	dB	%	dB	%	dB	%	dB
RGB	0.598	45.402	10.519	50.363	7.78	48.993	3.324	46.765
R	0.366	45.287	9.741	49.974	7.063	48.635	2.649	46.428
G	0.376	45.257	7.571	48.855	7.261	48.7	2.696	46.417
B	0.287	45.247	9.285	49.746	7.798	49.003	3.08	46.643



а



б

Рис. 5. Value Diagrams PSNR: *а* — HF filtration; *б* — LF filtration

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 the 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 steganalization from the condition of embedding containers into different colour components.

LITERATURE

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МЕТОДИ ЦИФРОВОЇ ФІЛЬТРАЦІЇ ТА ЇХ ВПЛИВ НА ЯКІСТЬ ЗОБРАЖЕНЬ РІЗНИХ КЛАСІВ

Проаналізовано та досліджено різні методи фільтрації та класи цифрових зображень. Реалізовано метод частотної фільтрації для цифрових зображень, досліджено міру спотворення цифрового зображення, залежно від класу зображення, окремо для кожної компоненти колірної моделі RGB. При дослідженні цифрових статичних зображеннях різних класів використані методи частотної фільтрації. Отримано процедури видалення сегментів спектру трьох колірних гам Зазначена статистика може бути базовим підґрунтям подальших досліджень для розробки сучасних ефективних методів стеганографії та стегоаналіза.

Ключові слова: методи частотної фільтрації, методи просторової фільтрації, цифрове зображення, стеганографія, міра спотворення цифрового зображення.

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МЕТОДЫ ЦИФРОВОЙ ФИЛЬТРАЦИИ И ИХ ВЛИЯНИЕ НА КАЧЕСТВО ИЗОБРАЖЕНИЙ РАЗЛИЧНЫХ КЛАССОВ

Проанализированы и исследованы различные методы фильтрации и классы цифровых изображений. Реализован метод частотной фильтрации для цифровых изображений и исследована мера искажения цифрового изображения, в зависимости от класса изображения, отдельно для каждой компоненты цветовой модели RGB. При исследовании цифровых статических изображений разных классов, использованы методы частотной фильтрации. Получены процедуры удаления сегментов спектра трёх цветовых гамм Указанная статистика может быть базовым основанием дальнейших исследований для разработки современных эффективных методов стеганографии и стегоанализа.

Ключевые слова: методы частотной фильтрации, методы пространственной фильтрации, цифровое изображение, стеганография, мера искажения цифрового изображения

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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.

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