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METHODS OF DIGITAL IMAGE IMPROVEMENT AND ITS STRUCTURE RESTORATION

The paper considers methods of digital image quality improvement, principles of digital image processing in frequency area by means of Fourier transformation. There had been suggested to use nonlinear filtration for solution of such problems as noise elimination, restoration of damaged parts of image.

***Key words**: digital image, improvement of image quality, frequency processing methods, Fourier transformation, algorithm of image filtration, nonlinear methods of filtration.*

Introduction

Nowadays the sphere of science and technology where systems of information processing, using data in digital form is rapidly developing . Systems of digital conversion of information are basic components of such systems, they serve for conversion of natural and artificial objects which are data carriers in analogue form into digital form. Data in digital form are used for storage, transfer, analysis and processing in systems of information digital processing.

Geoinformation systems is one of main types of information systems, using digital data, where methods of remote probing of the Earth, natural and artificial objects are widely used. Methods of remote probing are based on registration of electromagnetic radiation in wide spectral range and its further analysis. The main processing task is faults elimination, decrease of influence on distortions and noise, image conversion into convenient for human operator observation. Processing methods of aerospace images play especially important role. Efficiency of aerospace methods of Earth surface investigation, surface of other planets to large extent is determined by digital materials quality. Quality improvement of such images is important economic factor, since it reduces cost of operations fulfillment at the expense of survey scale reduction.

Analysis of existent approaches to the solution of problems aimed at improvement of digital image and its structure restoration

Existent approaches to the solution of problems aimed at improvement of digital image and its structure restoration are divided in two categories:

1) processing methods in spatial area (spatial methods), based on direct manipulation with image pixels;

2) processing methods in frequency area (frequency methods), based on signal modification (filtration), formed by means of Fourier transformation.

Spatial processing is applied when singular source of distortions is additive noise. Frequency filtration may be used for fuzzy images with illumination faults as well as noise [1]. Consequently, frequency processing is more general and widespread method of digital image quality improvement.

Description of image processing method in frequency area

The essence of this method consists in image representation as two-dimensional function $f(x, y)$, where x and y – are coordinates in space (more precisely, on plane). Value of f in any point set by the pair of coordinates (x, y), is called intensity or level of grey in this point.

It is well known statement, that any function that periodically repeats its own values, may be shown in sine and cosine sums of different frequencies, multiplied by some coefficients. Such function representation is called representation in the form of Fourier series. If the function is not periodic, but the area under its graph is finite then it is Fourier transformation.

Function specified both by series and Fourier transformation, can be completely restored without the loss of any information by means of transformation algorithm. This property is very important, as allows to operate in «Fourier - space», then return in initial area of function determination without any information losses [2]. Fig. 1a shows complex function, which is the sum of four sinusoids and cosine curves see in Fig. 1b.

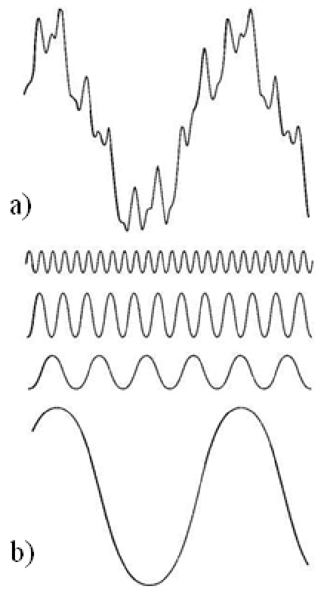

Fig. 1. Function decomposition into components: a) function; б) its components

Since digital images are described by two-dimensional discrete functions, let us consider discrete Fourier transformation (DFT) namely for these functions.

Let *f(x, y)*, if x = 0,1,2..., M - 1 and y = 0,1,2..., N - 1, specify image M×N. Two-dimensional discrete Fourier transformation of image *f(x, y)*, is reflected as *F(u, v)* and is set by the equation (1).

$$F(u,\nu) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-j2\pi(ux/M+\upsilon y/N)}\ , \qquad (1)$$

where u=0,1,2..., M - 1 and ν=0,1,2..., N - 1; M i N – are even numbers.

Coordinate system setting arguments *F(u, v) by* frequency variables u and v, is called frequency area. In this case we may find the analogy to arguments setting *f(x, y)* by spatial variables x and y. Rectangular of M×N, dimensions if u=0,1,2..., M - 1 and ν=0,1,2..., N - 1, is commonly accepted to call frequency rectangular. It has the same dimensions as the initial image.

If image *f(x, y)* is valid, its Fourier transformation, as a rule, is complex. The main method of visual analysis of this transformation consist in its spectrum calculations (i. e. absolute value *F(u, v)*) and its display image. Let *R(u, v)* i *I(u, v)* specify real and imaginary components of *F(u, v)*, then Fourier spectrum is set by the following expression (2).

$$\left| \ F(u,\nu) \ \right| = \left[R^2(u,\nu) + I^2(u,\nu \right]^{1/2}. \qquad (2)$$

Each element of Fourier pattern F(u, v) contains all starting points of f(x, y) function, multiplied by exponential members values, hence it is impossible to set direct correspondence between characteristic details of the image and its pattern. But certain general conclusions concerning interrelation of frequency components of Fourier pattern and spatial characteristic of image can be made. For instance, since frequency is directly related to signal change rate, it is clear that frequencies of Fourier transforms are connected with brightness variation in the image. The most slowly changing (constant) frequency component (u=ν=0) coincides with average brightness of the image. Low frequencies, corresponding to points located near the origin of coordinates of Fourier transforms correspond to slowly changing components of the image. In the image of the room, for instance, they can correspond to gradual changes of brightness of walls and floor. At a distance from origin of coordinates higher frequencies begin to correspond to more intense changes of image details brigtness and its sides.

Algorithm of image filtration in frequency area

The procedure of algorithm filtration in frequency area is simple and comprises such steps:

1. Initial image is multiplied by $(-1)^{x+y}$, in compliance with the expression (3). This is executed to make Fourier transformation centred, i.e. start of coordinates for function pattern will be in the center of frequency rectangular, in the point (M/2; N/2).

$$\xi\left[f(x,y)(-1)^{x+y}\right] = F(u - M/2, v - N/2). \quad (3)$$

2. Direct image DFT *F(u, v)*, obtained after step 1 is calculated;
3. Function *F(u, v)* is multiplied by some filter function *H(u, v);*
4. Inverse DFT as result of step 3 is calculated;
5. Necessary quotient of result of step 4 is allocated;
6. Result of step 5 is multiplied by (- 1)x +y.

The reason why factor H(u, v) is called filter (the term transfer function of filter is often used) is, that it suppreaa some "redundant" frequencies of transform but other are left almost without any changes. The problem of finding the transfer function of filter is a key problem, since it determines filtration method and specifies which frequencies will be filtrated [3].

Let *f(x, y)* denote input image after step 1, and *F(u, v)* its Fourier pattern. Fourier pattern of initial image is determined by the expression (4).

$$G(u,v) = H(u,v) \cdot F(u,v). \quad (4)$$

Functions multiplication of two variables *H* and *F* is fulfilled element-wise. Filtered image is obtained by means of calculation of inverse Fourier transform from Fourier pattern $F(u,v)$ calculating by the formula (5).

$$\text{Improved image} = \xi^{-1}\left[G(u,v)\right]. \quad (5)$$

Image to be found we obtain by allocation of the real part from the last result and multiplication by $(-1)^{x+y}$ to compensate the effect of input image multiplication by the same value.

The described procedure of filtration algorithm is schematically shown in Fig 2 in more general form, including the stages of preliminary and final processing .

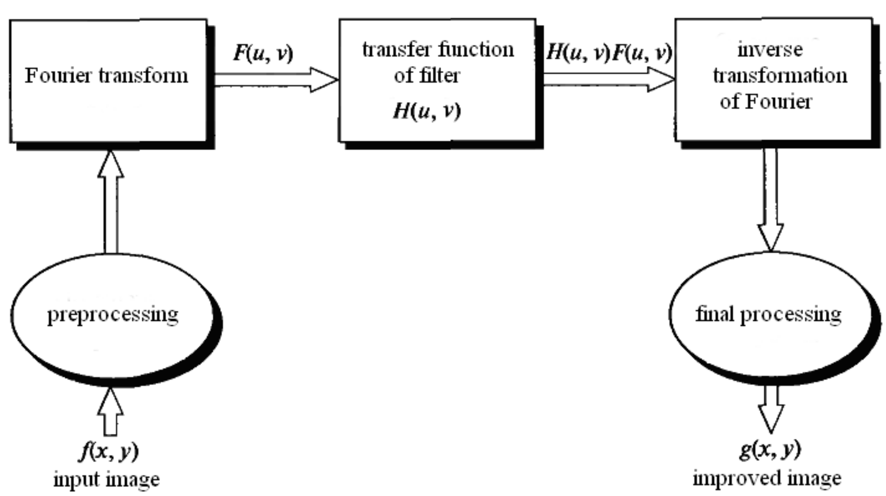

Fig. 2. Main filtration steps in frequency area

This filtration scheme may have some changes, connected with the necessity to reduce the input image, scaling of brightness and etc.

The example of filtration in frequency range is processing of aerospace images for geoinformaion systems and human-operator. Filtration results of the image in frequency range are shown in Fig. 3 where origin illumination in the filtrated image is reduced.

The drawback and subject of investigation of all filtration methods in frequency area is impossibility of ideal filter creation, which would reject all "redundant" frequencies and restoring at the same time image quality.

a) b)

Fig. 3. Filtration results in frequency range:
a) filtrated image; b) original image

Nonlinear methods of filtration

Nonlinear methods of filtration belong to one of the processing methods of image processing in frequency area. Class of nonlinear digital filters is wide to carry out their description in general form. Let us consider one of the known methods of the family of nonlinear digital filters.

Boundary problem of evaluation in points of zero row and zero column occurs during real images filtration of restricted size. Natural solution is using of conventional (one-dimensional) Kalman filtration.

Yolkap and Choens suggested to use Viner's filtration to eliminate film grain noise in model of the image system, described by the formula (6).

$$\tilde{y}_{i,j} = y_{i,j} + \alpha\left[y_{i,j}\right]^{1/3} n_{i,j}\,, \tag{6}$$

where α – constant value.

There had been obtained frequency characteristic of renovating filter for this model, that correspondes to the case of the infinite image, described by equation (7).

where $W_{F1}(\varpi_x, \varpi_y)$ – is energy spectrum of ideal image, E – is designation of mathematical forecast.

Nader and Savchuk elaborated procedure of the Viner's estimation of the discreet images, based on photographic recording of the image. This model takes into account chemical effects of the photographic process such as nonlinearity of the characteristic curve and boundary effects caused by developer diffusion as well as film grain noise. The advantage of the considered Viner's evaluation is, that it is based on the model of the general form: (due to its adaptability it is able to be modified in accordance with the change of the first and second moments of the random field, represented by the ideal image [4]).

Zweig elaborated heuristic nonlinear method for restoration of the low-contrast images to decrease noise of the film grain. Input image unrolles with high resolution capicity and each of its element is quantized by high quantity of levels during the `usage of this method. Subsequently, image of reduced clearness is obtained, joining elements into fragments, that do not intersect, of the size 2×2. Usually, the blur-free image has more sharp boundaries than image with reduced clearness, but noise dispersion of the latter is smaller. In case of white noise, dispersion of the fuzzy image is 4 times smaller than that of clear image, that is the consequence of elements spatial averaging. Averaged image is iteratively quantized using equable scale, quantization step being chosen to be equal to the value of noise mean square deviation, increased 4 times. Quantization error of 5 % by Gaussian noise is provided, due to such choice. Obtained quantized elements of the fuzzy image are researched in the area of 3×3 elements size [5].

If the central element of the fuzzy image is located on the boundary (fig. 4), it is divided into 4 elements, corresponding to full resolution capacity; levels are assigned to these new elements, that depend both on levels, corresponding to output elements of the sharp image, and on the nearest elements levels of the fuzzy image.

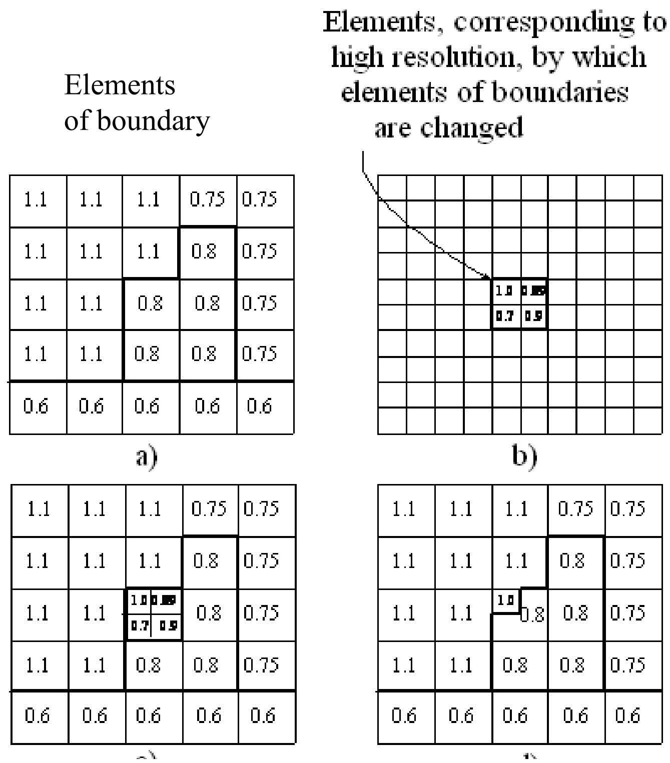

Fig. 4. The example of the noise elimination algorithm in accordance with Naderi: a) array that corresponds to reduced resolution capacity; b) array that corresponds to high resolution capacity; c) change of element that belongs to boundary; d) final result

It may happen , that all eight peripheral elements have been quantized with one level, but central element with another level. In this case it is assumed that central isolated element contains an error, caused by the noise, and intermediate level of peripheral elements is assigned to it. The simple algorithm is, that element, that corresponds to high resolution capacity is assigned the level of one of four associated elements (elements “North” and “East” or “North” and “West”, etc.), nearest to the level of the element being searched.

Conclusions

Main existent approaches to the solution of problems aimed at improvement of digital image and its structure restoration are considered. There has been analyzed image processing method in frequency area and its mathematical model. Filtration algorithm in frequency area has been considered and step - wise operation scheme for improvement of image quality have been presented.

One of the types of image processing methods in frequency area – nonlinear filtration has been shown. There has been considered one of the known methods of nonlinear filtration for noise elimination and original image improvement. Nonlinear filters may be used for solution of such tasks as noise elimination, restoration of damaged images, contrast ratio improvement, image contours allocation etc.

REFERENCES

1. Грузман И. С. Цифровая обработка изображений в информационных системах: Учебное пособие. / И. С. Грузман, В. С. Киричук, В. П. Косых, Г. И. Перетягин, А. А. Спектор. – Новосибирск: Изд-во НГТУ, 2000. – 168 с.
2. Фурман Я. А. Цифровые методы обработки и распознавания бинарных изображений. / Я. А. Фурман, А. Н. Юрьев, В. В. Яншин. – Красноярск: Изд-во Краснояр. ун-та, 1992. – 248 с.
3. Хуанг Т. С. Быстрые алгоритмы в цифровой обработке изображений / Т. С. Хуанг, Дж.-О. Эклуид, Г. Дж. Нуссбауыер н др.; пер. с англ.; под ред. Т. С. Хуан га.: – М.: Радио и связь, 1984. – 224 с.
4. Богнер Р., Введение в цифровую фильтрацию. / Р. Богнер, А. Константинидис. – Москва.: Мир, 1976. – 216 с.
5. Рабинер Л.. Теория и применение цифровой обработки сигналов / Л. Рабинер, Б. Гоулд; пер. с англ.; под ред. Ю. Н. Александрова. – М.: Мир, 1978. – 848 с.

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