IRSTI 49.40.01
UDC 004.92

Using wavelet transform in image processing

E. Daiyrbayeva[2], F. Murzin[3], A. Yerimbetova [1,2], A. Toigozhinova[2]
[1]Institute of Information and Computational Technologies,Almaty, Kazakhstan
[2]Kazakh academy of transport and communications named after M. Tynyshpaev, Almaty, Kazakhstan
[3]A.P. Ershov Institute of Informatics Systems SB RAS, Novosibirsk, Russia
[1]nurbekkyzy_e@mail.ru, [3]aigerian@mail.ru,[4]aynur_t@mail.ru
[1]ORCID ID: https://orcid.org/0000-0002-4255-5456
[2] ORCID ID: https://orcid.org/0000−0002−4644−5406
[3]ORCID ID: https://orcid.org/0000-0002-2013-1513
[4]ORCID ID: https://orcid.org/0000-0002-0305-2776

Abstract. At the present stage of globalization, the problem of information security remains relevant. It is necessary to commend the work of scientists in the areas of the possibility of delivering information in a confidential form by various methods. This issue is one of the priority areas in the field of steganography.

This article discusses the possibility of using a wavelet transform for processing (improving) digital images by transferring them to the transformation domain, and after processing - restoration using the inverse transformation operation. Computer image processing involves the processing of digital images using a PC or specialized devices built on digital signal processors. In this case, image processing is understood not only to improve the visual perception of images, but also to classify objects that are performed during image analysis.

The wavelet transform provides the most visual and informative picture of the results of the experiment, allows you to clear the original data from noise and random distortions, and even "by eye" to notice some features of the data and the direction of their further processing and analysis.

Keywords: images, wavelet transform, noise, steganography.

New efficient methods of image processing became possible with the development of the theory of wavelets, which, in comparison with the Fourier transform, allow us to represent with much greater accuracy the smallest features of functions, images and signals, up to discontinuities of the first kind (jumps), with their binding to time or space coordinates. The term "wavelet" was introduced by Alex Grossman and Jean Morlet in the mid-1980s in relation to the analysis of seismic and acoustic signals. Currently, wavelets are used in image recognition tasks, in the processing and synthesis of various signals, in the analysis of images of different nature, for compressing large amounts of information.

Wavelet (born of wavelet - small wave, ripple,. also a surge, often - wavelet) - a mathematical function that analyzes the different frequency components of the data. The graph of the function looks like wave-like oscillations with amplitude decreasing to zero far from the origin.

The ideas of the theory of wavelets arose when a sufficient number of experimental data series appeared, the processing of which by the standard and well-developed method of the Fourier transform showed its limitations for finding regularities in them.The rapid development of computer technology also played a role, which made it possible to numerically solve such problems that were simply inaccessible before.

Practically important wavelets are traditionally defined as functions of a single real variable with real values. Depending on the mathematical model (structure, scope, structure the field of possible values and transformations) distinguish between discrete and continuous wavelets. Since the decomposition of signals in the wavelet basis is carried out using floating-point arithmetic, errors occur, the magnitude of which depends on the degree of approximation of the signal.

Images of various types are increasingly being used both for scientific and applied purposes and in everyday life. Many information transformation and data analysis tasks involve image processing and transmission. Accuracy of results depends on image quality.

Digital imaging continues to evolve today. In many industrial and scientific-applied fields, there are various tasks of digital image processing. Many questions have a complete solution. This refers to the problems of filtering, segmentation, object recognition in images, multimedia information processing, and digital television signal evaluation [1].

In computer systems, when the recipient of information is a person, methods of image enhancement are of great importance, which make it possible to increase the visibility of interesting details in the image. In addition, in the preprocessing of images performed in automatic computer systems, preprocessing of images also plays an important role, which makes it possible to form the space of objects' attributes [2].

The images obtained at the output of the optoelectronic converters are distorted by noise. When analyzing objects against a complex background, the background is also a hindrance. The weakening of interference is achieved by filtering. Filtering is done in the spatial or frequency domain, depending on the application.

Computer image processing involves processing digital images using computers or specialized devices based on digital signal processors. In this case, image processing is understood not only to improve the visual perception of images, but also to classify objects, performed in the analysis of images [3].

To carry out digital image processing, it is necessary to convert the continuous (analog) image signal into a digital array. This transformation involves performing two transformations. The first transformation is the replacement of a real continuous image with a set of samples at discrete times, such a transformation is called sampling. The second is the transformation of a continuous set of image signal values into a set of quantized values, such a transformation is called quantization.

The main stages of digital image processing are shown in fig. 1.

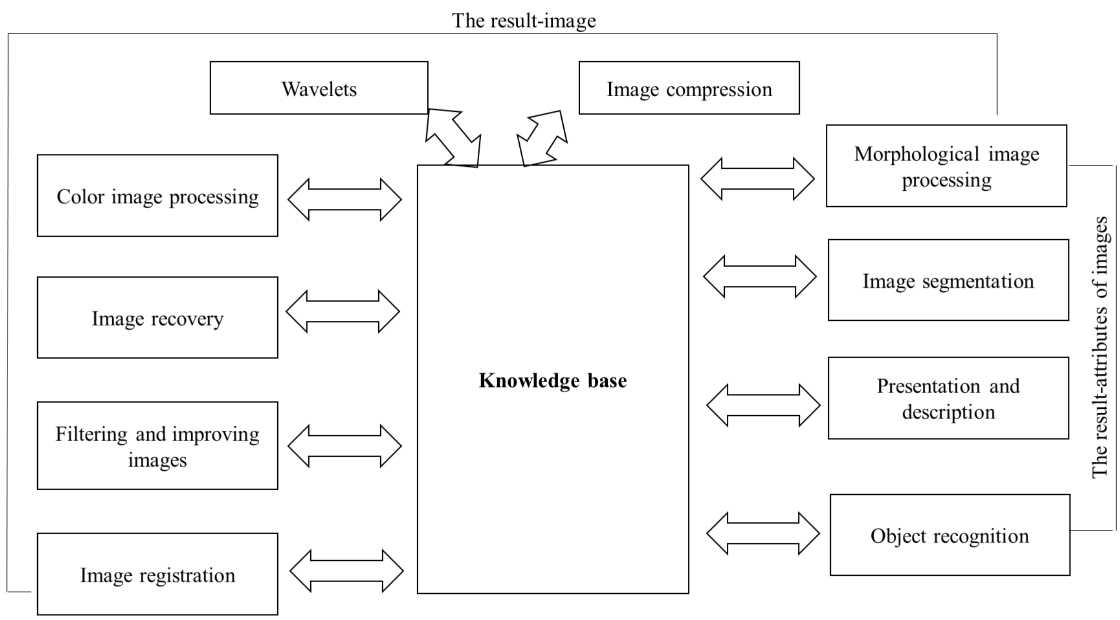


Figure - 1. Main stages of digital image processing

Analyzing the literature in this area, we can identify the following: the almost complete absence of methods for embedding compression-resistant multimedia data. One of the transformations that allows such embedding is the discrete wavelet transform [2,3]. As is known, a set of wavelets in their time or frequency representation can approximate a complex signal or image, both perfectly accurate and with some error. Wavelets have clear advantages in representing local features of functions and implicitly taking into account the features of the psychophysiological model of perception. Because of this, they are widely used for feature analysis, compression, and reconstruction of complex signals. We show that their application in the development of a steganography method focused on achieving maximum throughput (hidden transmission and storage of information) can solve the main problems of steganography, namely: minimizing introduced distortions and resistance to attacks by a passive attacker [4].

Wavelets are a generalized name for temporal functions that have the form of wave packets of one form or another, localized along the axis of the independent variable (t or x) and capable of shifting along it or scaling (compression-stretching). Wavelets are created using special basic functions - prototypes that specify their type and properties [5].

An image consisting of two dots with $\{x_1, x_2\}$. brightness is used. These values can be replaced by the mean a and half-difference d:

$$a = \frac{(x_1 + x_2)}{2}, d = \frac{(x_1 - x_2)}{2}$$

The "wavelet transform" of the original $\{x_1, x_2\}$ sequence is the $\{a, d\}$ sequence, knowing which you can restore the original values

$$x_1 = a + d, x_2 = a - d$$

In this view, information is not added or lost. But such a replacement can be useful if the values of x_1 and x_2 are close. In this case, the difference d is small and less memory can be used to store it, or you can drop d altogether and replace the "image" $\{x_1, x_2\}$ with an approximation of $\{a\}$. Thus, image compression is obtained. The restored image is $\{a, a\}$.

Considered a large "image" $\{x_1, x_2, x_3, x_4\}$. Average values and differences are calculated.

$$\begin{aligned} a_{1,0} &= \frac{(x_1 + x_2)}{2}, a_{1,1} = \frac{(x3 + x4)}{2} \\ d_{1,0} &= \frac{(x1 - x2)}{2}, d_{1,1} = \frac{(x_3 - x_4)}{2} \end{aligned} \tag{1}$$

Received a new representation $\{a_{1,0}, a_{1,1}, d_{1,0}, d_{1,1}\}$ "image", which contains the same values as the original. If you delete the numbers $d_{1,0}, d_{1,1}$, you get a compressed image of $\{a_{1,0}, a_{1,1}\}$. Applying the same procedure to the remaining image, you can write (2)

$$a_{0,0} = \frac{(a_{1,0} + a_{1,1})}{2}, d_{0,0} = \frac{a_{1,0} - a_{1,1}}{2} \tag{2}$$

or

$$a_{0,0} = \frac{a_{1,0} + a_{1,1}}{2} = \left(\frac{x_1 + x_2}{2} + \frac{x_3 + x_4}{2}\right) \Big/ 2 = \frac{x_1 + x_2 + x_3 + x_4}{4} \tag{3}$$

$$d_{0,0} = \frac{a_{1,0} - a_{1,1}}{2} = \left(\frac{x_1 + x_2}{2} - \frac{x_3 + x_4}{2}\right) \Big/ 2 = \frac{x_1 + x_2 - x_3 - x_4}{4} \tag{4}$$

Neglecting $d_{0,0}$, you can write the entire image $\{x_1, x_2, x_3, x_4\}$ with an image consisting of one number $\{a_{0,0}\}$ – with the average value of the brightness of all pixels. A value of $a_{0,0}$ represents the most approximate level of image information; information at the lowest resolution.

The values $\{a_{1,0}, a_{1,1}\}$, taken together, represent information at the next higher resolution level. They are expressed through $\{a_{0,0}, d_{0,0}\}$ by the formulas (5)

$$a_{1,0} = a_{0,0} + d_{0,0}, a_{1,1} = a_{0,0} - d_{0,0} \tag{5}$$

The original pixel values / luminances of $\{x_1, x_2, x_3, x_4\}$ represent the highest image resolution. These values can be restored by calling (6)

$$x_1 = a_{1,0} + d_{1,0}; x2 = a_{1,0} - d_{1,0}; x3 = a_{1,1} + d_{1,1}; x4 = a_{1,1} - d_{1,1} \tag{6}$$

Taking into account, (1), (3) and (4), the "wavelet transform" of the original image is determined by the formulas (7):

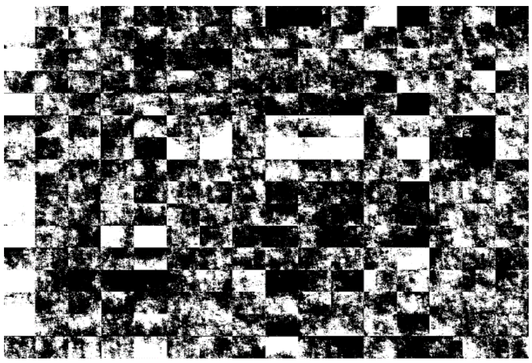
$$\begin{aligned} a_{0,0} &= \frac{x_1 + x_2 + x_3 + x_4}{4}, d_{0,0} = \frac{x_1 + x_2 - x_3 - x_4}{4} \\ d_{1,0} &= \frac{x_1 - x_2}{2}, d_{1,1} = \frac{x_3 - x_4}{2} \end{aligned} \tag{7}$$

Based on the above, as an example (1-7), several images were tested, with different sizes of data shown in fig.2, here are the results of some experiments ("Nature" with a resolution of 1024 × 1024 pixels) [5,6].

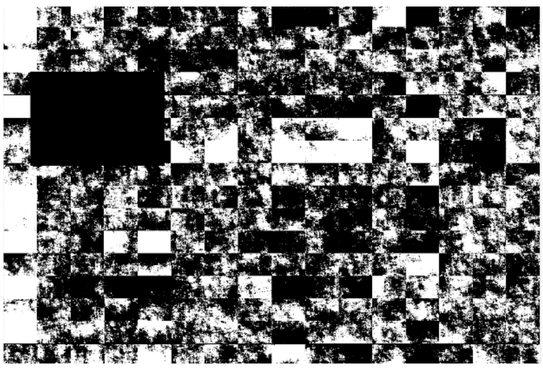
The result of the wavelet transform is an ordinary array of numerical coefficients. This form of representation of information about the image is very convenient, because numerical data is easy to process. So, the image processing takes place in two stages – the first stage is compression with loss of information (wavelet transform), the second-the usual data archiving. To restore the image, you must repeat all the steps in reverse order. First, the value of the coefficients is restored, and then, using the inverse wavelet transform, an image is obtained.

The presented computer program functions as follows: first, the file is read into the pixel matrix then the program does a standard wavelet transform of the image and saves the result to a file. The results can be seen in Figure 2 (b-e).

a) original image

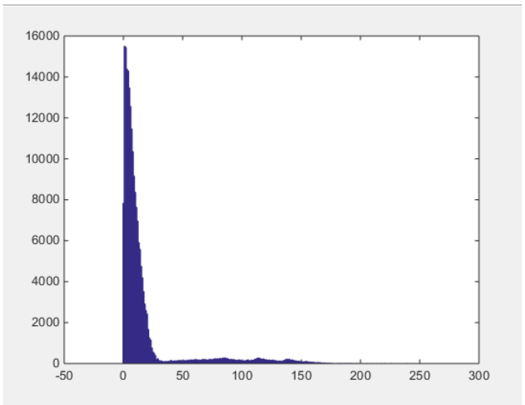


b) fragmented image



c) fragmented image with noise

d) Conversion result



e) histogram

Figure - 2. Test results

Image quality can be determined by statistical, spectral, and brightness characteristics of the image. In most practical applications, quality is considered as a measure of the proximity of two images: real and ideal, or transformed and original.

Image enhancement. In computer systems, the source images and data processing results are displayed as an image on the screen, with the recipient of the information being an observer. The procedure that provides this representation is called visualization. It is desirable to use processing to give the output image such qualities that would make its perception by a person as comfortable as possible [2].

Eliminating noise in an image the need for noise reduction occurs if the noise level significantly degrades the image quality, preventing you from extracting useful information from it.To suppress noise, it is necessary to know its structure, which can often be estimated only from the image itself.

Conclusion. In recent years, when digital systems are increasingly replacing analog image processing systems, it is very important to master modern computer methods for describing and processing images.

Several images have been tested with different data sizes to be hidden. The program allows you to compare the original and resulting images, both visually and by calculating the signal-to-noise ratio, which allows you to mathematically evaluate a person's visual perception. Software experiments were carried out in the MatLab system.

Acknowledgments

This research has been is funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP08857179)

References

[1] R. Gonsales, R. Vuds. Tsifrovaya obrabotka izobrazheniy [in Russian: Digital image processing]-// M.: Tekhnosfera, 2005.

[2] R. Gonsales, R. Vuds. [in Russian: Eddins Digital Image Processing in Matlab]-// M.: Tekhnosfera, 2006.

[3] R. Ibrahim and T.S. Kuan, Steganography imaging system (SIS): hiding secret message inside an image, Lecture Notes in Engineering and Computer Science: Proceedings of The World Congress on Engineering and Computer Science 2010, San Francisco, USA, 2010, pp. 144-148.

[4] V.T.Fisenko, T.YU.Fisenko. Komp'yuternaya obrabotka i raspoznavaniye izobrazheniy [in Russian: Computer processing and image recognition] ucheb. Posobiye. - //SPb: SPbGU ITMO, 2008. – 192 s.

[5] P.G. Dolya. Metody obrabotki izobrazheniy [in Russian: Image processing methods]-// Khar'kovskiy Natsional'nyy Universitet mekhaniko – matematicheskiy fakul'tet 2013.

[6] P.G Dolya. Matematicheskiye metody obrabotki izobrazheniy [in Russian: Mathematical methods of image processing]-//Khar'kovskiy Natsional'nyy Universitet mekhaniko–matematicheskiy fakul'tet 2014.