Automatic Identification of Images with Autocorrelation and Cross Correlation Processing of Neural Network

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Abstract

The following opportunities of making the correct decision during processing of the neural network on the image according to two selected trajectories have been analyzed: 1) by comparison of correlation factors of received signals; 2) by correlation analysis of peak modulations spectrum and 3) by processing auto- and cross correlation functions of the master image and the image under investigation. It is shown, that the relation of dispersions of Fourier-portrait spectrum amplitudes and the relation of the ranges of cross correlation functions is the most optimal for change of analyzed images.

1 Introduction

Recognition of images and their identification for authenticity is an intricate problem, both from the scientific point of view and in instrument implementation. For majority of practical applications, e.g. identification of passports and bank notes [1], recognition of license plates [2, 3], analysis of technical condition of operating complex mechanical system [4-6], etc. the necessity to make the correct decision arises.

In most cases the decision is made by processing a large quantity of attributes of recognition in real time. It has required for application of digital methods of image processing using computer. The theory and the methods of image recognition are based on application of artificial intelligence. A special place in this sphere is occupied by neural networks created on images. As the basic numerical characteristics of the images under investigation in the works [7,8] it is offered to use the following characteristics of one-dimensional casual process on specified trajectories in the neural network: mathematical expectation, root-mean-square deviation (dispersion), asymmetry factors and excess, entropy, value of minimal and maximal elements of the analyzed field and the range (range of levels).

During the analysis of images with the purpose of their recognition and identification one has to face high quality imitation. Development of up-to-date polygraphy helps to implement such quality. [8] Various moments examined in this paper in the probability theory do not allow to make correct decisions with high degree of their probability. In this connection the **goal is**: to apply the correlation and spectral analysis of images on the specified neural network with definition of autocorrelation and cross correlation functions.

For achievement of the assigned goal it is necessary to solve the following problems: - to develop an optical scheme of image acquisition in various wave lengths of the optical range; - to determine the conditions of creation of a neural network on the image; - to create hardware architecture of the image processing with acquisition of autocorrelation and cross correlation functions on various trajectories of the neural network.

2 Acquisition of image, creation of a neural network and the methods of processing

For image acquisition a panoramic scanner or a digital camera are used. The scheme of the image acquisition and the structure of digital processing of signals are shown in fig. 1.

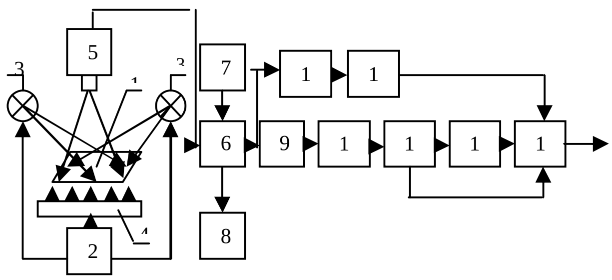

Figure. 1. General scheme of image acquisition and processing.

The image under investigation is put on the objective table 1. Illumination is made by a set of light-emitting diodes 3 or by an areal source 4. Unit 2 serves for color and irradiation intensity control. A color camera or a color panoramic scanner form the image under investigation which is entered into the system unit of the computer 6. Unit 7 contains the program which reads the information on certain trajectories of the neural network.

Unit 8 measures the color, and the color in the form of a code signal enters the spectrum analyzer input 9. If the measurement of the contrast received in transmitted or in reflected light is carried out, the signal is supplied directly from the system unit to the spectrum analyzer input.

As an example, fig. 2 shows the initial signal received in reflected light on two different trajectories from the standard and from the image under investigation.

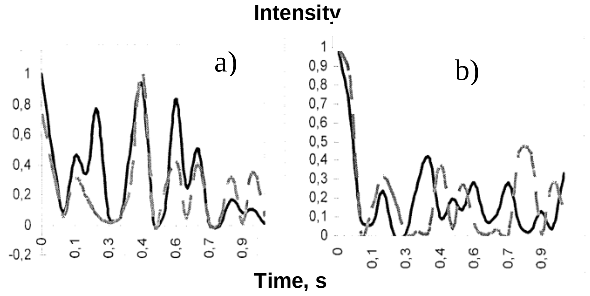

Figure 2. The initial signal rec... d in reflected light for the first and second trajectories of the neural network:
a) standard;
b) the sample under investigation

The time during which the signal on each trajectory has been received, made 1 second. The value of the relative contrast in 0.05 sec was entered into the unit 10. Supposing that the signal is casual, the factors of correlation were calculated in unit 10 according to the values of which the decision was made regarding the specified threshold in unit 11. Received information is stored in unit 15 and used in future for making the final decision.

The spectrum of peak modulations which is used in the unit 12 for formation of Fourier portrait of the signals from all four trajectories of the standard and the image under investigation is supplied to the output of the spectrum analyzer 9. In the unit 13 the correlation analysis of the obtained spectrum of peak modulations is carried out.

Unit 14 is used for calculation of auto- and cross correlation functions and makes their preliminary analysis. The final decision by comparison with the standard is obtained in unit 15 and displayed on the information board or supplied to control in case of analysis of operation of a complex mechanical system.

3 Correlation processing of signals

Selection of trajectories in a neural network is determined by the correlation factor, which for convenience of programming is represented in the following form [9]:

$$r = \frac{x \cdot y - \bar{x} \cdot \bar{y}}{\sqrt{x^2 - \bar{x}^2}\sqrt{y^2 - \bar{y}^2}} \quad (1)$$

where $\bar{x}$ and $\bar{y}$ are the mathematical expectation of random variables of the set X and Y; x·y is the mathematical expectation of the product of random variables x and y; $\sqrt{x^2 - \bar{x}^2}$ and $\sqrt{y^2 - \bar{y}^2}$ are dispersions of random variables x and y accordingly.

The correlation factor of samples on specifically selected first and second trajectories for the standard makes 0,596, and for the sample under investigation it makes 0,579. The obtained values indicate that the selection of trajectories for construction of a neural network should satisfy the following inequality:

$$r \le 0{,}6, \quad (2)$$

As the image under investigation is not identical to the standard, the identity assessment criterion should be presented in the following form:

$$0{,}015 \ge K_1 = \sqrt{\Delta r^2 / n} \ge 0{,}015, \quad (3)$$

If $K_1 \le 0{,}015$, the image under investigation is identical to the standard, and if $K_1 \ge 0{,}015$, the image under investigation is not identical to the standard. The result of comparison with the standard enters unit 15 for formation of the final decision.

In case of accurate imitation of the image under investigation according to the criterion (3) it is not always possible to make the correct decision. In this case there is necessity to carry out a deeper analysis.

4 Spectral analysis of received signals

Analyzed signals are described by random functions. Therefore their more careful analysis is carried out by obtaining the spectral structure of peak modulations of the received signals from the standard and the image under investigation. For this purpose the signals are supplied to the input of the spectrum analyzer periodically with the frequency not exceeding the sensitivity of the spectrum analyzer. If the signal passage time is T (the period of their recurrence), on the output of the spectrum analyzer we receive the following function:

$$u(t) = \sum_{i}^{n} A_i \cos\left(i \frac{2pt}{T} \right), \quad (4)$$

where A_i is the frequencies amplitudes $w_i = i \frac{2p}{T}$, and the index i takes arbitrary values.

Formula (4) represents the spectrum of peak modulations, and the function $u(t)$ is the initial signal coming to the input of the spectrum analyzer. Obtained spectra of peak modulations for two analyzed trajectories are shown in table 1.

Table 1: The spectra of peak modulations obtained on the output of the spectrum analyzer and related to the signal on the output of the measuring system

Parameters	Harmonic numbers				
	1	2	3	4	5
Standard 1st trajectory	0,1/5	0,3/10	0,4/25	0,8/37	0,2/48
Standard 2nd trajectory	0,4/7	1/12	0,7/23	0,6/36	0,5/50
Investigated 1st trajectory	0,12/5,2	0,29/9,9	0,41/26	0,82/38	0,18/47
Investigated 2nd trajectory	0,39/6	1/13	0,71/22	0,69/37	0,51/48

Fourier portrait is calculated for the function (4). Obtained spectra in essence are the Fourier portrait from both trajectories of the neural network for the standard and the image under investigation. Both Fourier portraits are shown in figure 3.

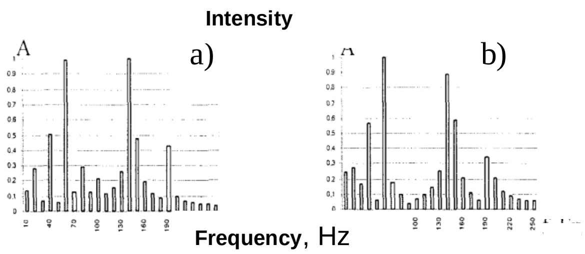

Figure. 3. Peak-frequency spectrum of Fourier portrait:
a) for the standard;
b) for the investigated sample

One can consider the values of amplitudes of each harmonics to be casual and then it is possible to determine the factor of cross correlation both inside of the image on two trajectories, and between the standard and the object under investigation. The results are shown in table 2.

Table 2: Correlation factor for various trajectories and a root-mean-square deviation of amplitudes of various harmonics

PARAMETERS	COMBINATIONS OF THE TRAJECTORIES UNDER INVESTIGATION					
	STAND. 1st - 2 nd	INVESTIG. 1st - 2nd	1st –STAND. 1st–INVESTIG.	1st –STAND. 2nd–INVESTIG.	2nd –STAND. 1st–INVESTIG.	2nd –STAND. 2nd –INVESTIG.
r	0,987	0,987	0,995	0,975	0,975	0,997
$\sqrt{\Delta A^2/n}$	$1{,}07\cdot10^{-4}$	$1{,}39\cdot10^{-4}$	$1{,}89\cdot10^{-5}$	$1{,}24\cdot10^{-3}$	$1{,}24\cdot10^{-3}$	$2{,}84\cdot10^{-5}$

The correlation factor of peak-frequency characteristics between two trajectories inside of each image for the standard and the image under investigation is high enough. The correlation factor on spectral components for identical cross trajectories is even higher. The correlation factor of peak spectral components noticeably decreases for cross components of different trajectories. The difference between the correlation factors is not enough to make the correct decision. Therefore it is offered to develop another criterion.

For this purpose we'll consider a root-mean-square deviation of amplitudes for identical frequencies of the following type:

$$s = \sqrt{\Delta \boldsymbol{A}^2 / \boldsymbol{n}}\,, \qquad (5)$$

where n is the number of examined harmonics. The calculated values of a root-mean-square deviation for trajectories of different combinations are presented in table 2.

The relation of a root-mean-square deviation of cross trajectories of the standard and the object under investigation to a root-mean-square deviation of amplitudes of different frequencies for different trajectories of the standard, i.e. $s_{\boldsymbol{i}} / s_0$, is used as the criterion of the assessment "identical" - "not identical". Such relation differs by an order and consequently is more reliable criterion for making the correct decision. However it can be not enough for making the final decision. Therefore we'll consider the opportunities which autocorrelation and cross correlation functions can implement.

5 Autocorrelation and cross correlation functions

For a quantitative assessment of difference of the signal $\boldsymbol{u}(\boldsymbol{t})$ and its copy $\boldsymbol{u}(\boldsymbol{t} - t)$ displaced in time, autocorrelation function as the average value of scalar product of the signal and its copy on the average for the period [10] is entered

$$\boldsymbol{ACF} = \frac{1}{\boldsymbol{T}} \int_0^{\boldsymbol{T}} \boldsymbol{u}(\boldsymbol{t}) \boldsymbol{u}(\boldsymbol{t} - t) \boldsymbol{dt}\,, \qquad (6)$$

where T is the period of the signal recurrence. Formula (6) determines the average interpower of two integrated functions $\boldsymbol{u}(\boldsymbol{t})$ and $\boldsymbol{u}(\boldsymbol{t} - t)$.

If different signals of $\boldsymbol{u}(\boldsymbol{t})$ and $\boldsymbol{v}(\boldsymbol{t})$ types interact, their interpower is determined by the average cross correlation function for the period [10]:

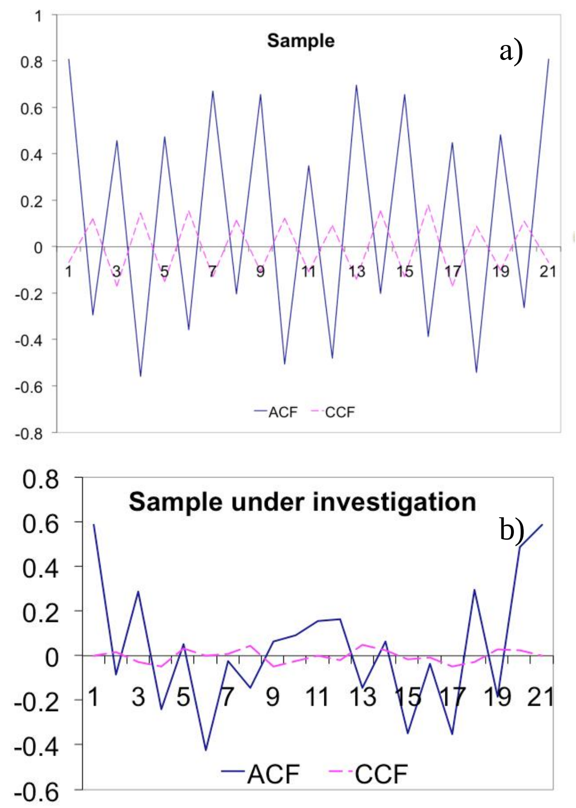

Fig.4. Autocorrelation function of the first trajectory and cross correlation function: a) the standard; b) sample under investigation

$$CCF = \frac{1}{T}\int_0^T u(t)v(t-t)dt \ , \qquad (7)$$

As an example fig. 4 shows the values of these functions for the standard and the image under investigation. If we consider the received autocorrelation functions as the functions of random variables, their correlation factor with reference to the standard for a particularly chosen trajectory makes 0,745. The received value of the correlation factor is considerably lower than it was for initial functions (see table 1), but remains high enough.

Cross correlation function for the standard differs from the autocorrelation function (see fig. 4). That's why the correlation factor in this case is even negative, and it means that connection between these functions is completely absent. In such case it is necessary to take advantage of the root-mean-square deviation of the values of these functions in the chosen points of the analysis according to the formula (5). The result of calculations for autocorrelation function of the first trajectory and cross correlation function of the standard made 0,387, and accordingly for autocorrelation function of the second trajectory it made 0,153. Approximately two-time difference is not convincing and cannot serve as the criterion for decision-making.

Considering a marked difference between autocorrelation and cross correlation functions for the standard and the image under investigation, is of interest to examine the relation of the average range of these functions for the standard with regard to the image under investigation as the criterion of for decision-making, i.e.

$$K = \bar{A}_{samp.} / \bar{A}_{invest.} , \qquad (8)$$

For cross correlation functions this relation makes 5,3, and for autocorrelation functions of the first trajectory it makes 2,25 and for the second trajectory it makes 1,46. Hence, the relation of the range as the criterion of making the correct decision can be used only for cross correlation functions received inside of the standard and the image under investigation for specified trajectories of the neural network.

The relation of the ranges for cross correlation functions in comparison with autocorrelation and cross correlation functions of the standard does not surpass 3,5. Such small difference is caused by the fact that the standard is used together with the object under investigation, and this is not allowed.

6 Conclusion

Thus, the researches have shown, that in automatic machines for image recognition on their pictures using the neural network which processing is carried out by application of spectral and correlation methods on each trajectory is quite real and allows to identify objects and to make correct decisions even in case of small deviations from the standard. Thresholds of decision-making shall be established in each concrete case and continuous self-training shall be used. The standard should not be used together with the object under investigation during its analysis.

7 Reference

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