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The analysis of methods effectiveness of automated non-destructive testing of products based on Data Mining methods

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Abstract. Purpose of the study: the analysis of the effectiveness of automated nondestructive testing methods within the objectives of data clustering on the use of short-wave electromagnetic radiation in flaw detection. Research methods: Kohonen self-organizing maps (SOM). The relevance of the work is that due to the increased demand for quality and reliability of products are becoming increasingly important physical methods for automated control of metals and products thereof that do not require cutting or fracture specimens of finished productes. The article noted common features of methods of short-wave electromagnetic control of products. The effectiveness of the Data Mining approach to the construction of a hypothesis on the interrelationships of data groups on non-destructive testing of products is substantiated. As an instrument, the method of self-organizing Kohonen maps was chosen. An example of a part of training data and neural network configuration parameters performing the task of visualization and clustering is given. It is concluded about the lead electromagnetic methods of automated control of complex products in production. The resulting distance matrix and the cluster map are shown. An example of applying the results of analysis to the problem of testing spot welded joints is considered. Given the further directions of research is to develop a computer image processing techniques in the framework of automated non-destructive testing systems.

1 Introduction

Due to the increased demand for quality and reliability of manufactured products, physical methods of control of metals and products from them, which do not require cutting out samples or destroying finished products, become more important.

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Thus, the process control system based on the results of diagnostics of technical objects are widely distributed in various industries. In particular, they include systems of optical control and diagnostics of welded joints, as well as non-destructive testing and diagnostics of parts and structures [1]. According to the research of the Russian scientist N.P. Aleshin [2] ian estimate of the detectability of defects by various types of NQM was drawn up. (fig. 1).

Based on the research, it can be concluded that the leaders in efficiency are the following methods: acoustic, radiation, optical and eddy current.

It is known that the energy of electromagnetic radiation increases with the frequency of the wave [3]. On the basis of this, shortwave methods, in addition to electromagnetic and radiation, can include capillary (using ultraviolet translucence), since all these methods have a common nature as a control mechanism, and principles for analyzing the results.

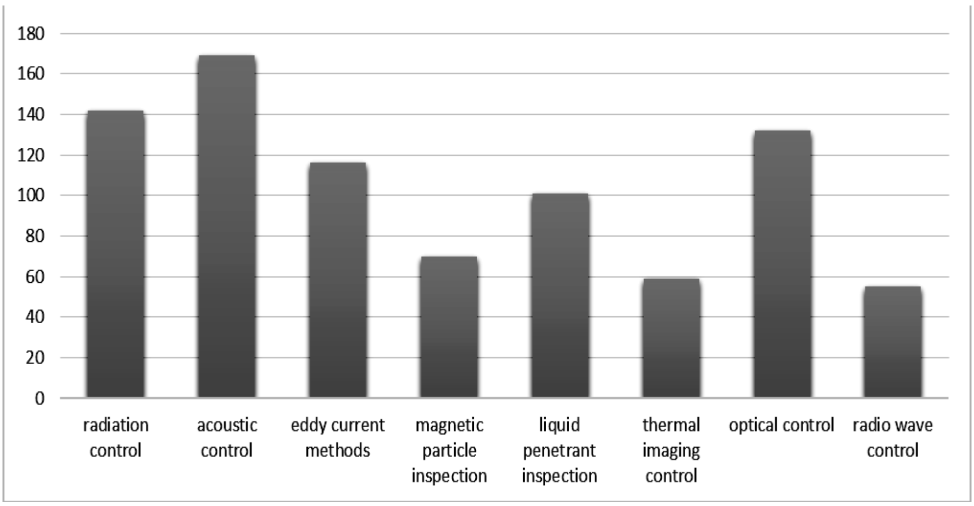

Fig. 1. Methods of nondestructive testing evaluation diagram.

2 Data Mining - analysis based on self-organizing maps of Kohonen

Let us analyze the relevance of methods using self-organizing Kohonen maps. This technology relates to the field of Data Mining analysis. Traditional methods of data analysis (statistical methods) are mainly oriented to checking verification-driven data mining and on "rough", exploratory analysis, which forms the basis of online analytical processing (Online Analytical Processing, OLAP), while one of the main provisions of Data Mining – the search for non-obvious patterns. Data Mining tools can find such patterns independently and also independently build hypotheses about interrelations. Since it is the formulation of hypotheses about dependencies is the most difficult task, Data Mining advantage compared with other methods of analysis is obvious. Most statistical methods to identify relationships in data use the concept of averaging over a sample, leading to operations on non-existent quantities, while Data Mining operates on real values.

A self-organizing map (SOM) or self-organizing feature map is a type of artificial neural network that is trained using unsupervised learning to produce a low-dimensional, discretized representation of the input space of the training samples, called a map, and is therefore a method to do dimensionality reduction. Self-organizing maps differ from other artificial neural networks as they apply competitive learning as opposed to error-correction learning (such as back-propagation with gradient descent), and in the sense that they use a neighborhood function to preserve the topological properties of the input space [4].

The general scheme of the network is shown in Fig. 2 [5].

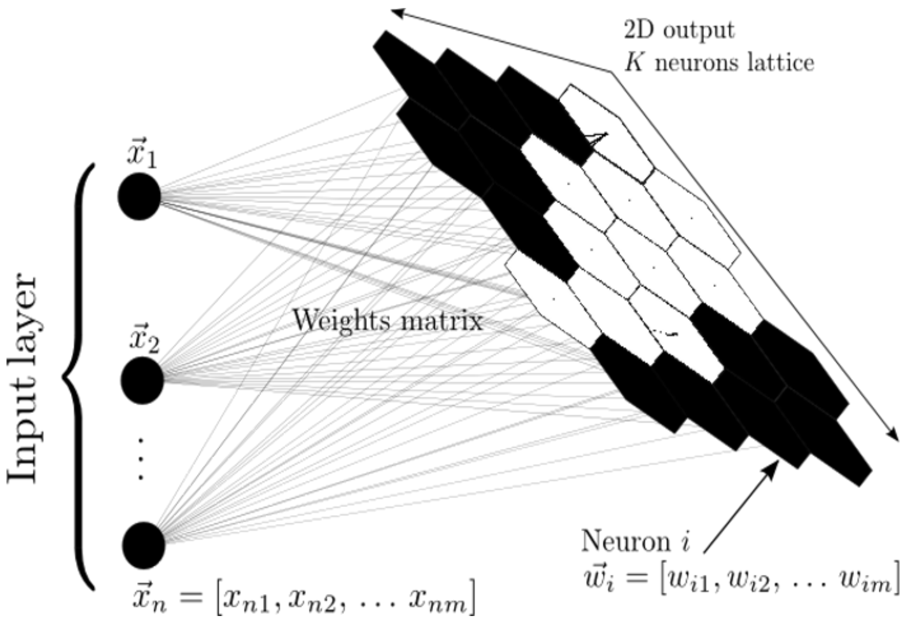

Fig. 2. Scheme of the SOM work.

Kohonen algorithm makes it possible to construct a neural network for dividing the input signal vectors on the subgroup. The network consists of n neurons, forming a rectangular lattice on the plane [6]. Elements of the input signals fed to the inputs of all neurons in the network. In the process of the algorithm, the synaptic weights of the neurons are tuned.

Input signals (vectors of real numbers) are sequentially imposed network. Desired output signals are not detected. After it had been charged with a sufficient number of input vectors, the network determines synaptic weights clusters.

To assign an object to a cluster need to find a cluster with a minimum distance from the object to the centroid of the cluster. Usually used for this calculation of the Euclidean distance or Hamming distance [7].

As a result of solving the clustering problem, a cluster map is obtained, where close-lying clusters correspond to the input vectors of the neural network that are closer to each other. All this allows you to perform a visual multi-parametric ordering information. It is important that in this case unexpected clusters of "close" data [8] can be detected, the subsequent interpretation of which by the user can lead to obtaining new knowledge about the object under study.

In a set of Input Layer data involved data to assess the effectiveness of control methods, production flaw market and the market offers for nondestructive testing services:

$$\textit{Input Layer} = [\textit{Method } [x1], \textit{Equipment offer } [x2], \textit{Service offer } [x3], \textit{Gross efficiency } [x4]], \quad (1)$$

where *xn* - a set of vector data of the same type and destination.

The group of input values rated on effectiveness scales are presented on the basis of the convolution of the data from Table 1.

Evaluation carried out in the form of a system, "5" - excellent, "4" - good, "3" - satisfactory, "1" - is not used.

The separation between the training set and the test – 95 and 5%. Groups of clusters assigned equivalent value.

As an input network, clustering was carried out in 6 regions according to the following groups of methods for nondestructive testing (Fig. 3, from left to right, from top to bottom: ultrasonic inspection, thermal imaging control, magnetic particle inspection, short-wave electromagnetic control methods, eddy current methods, visual inspection).

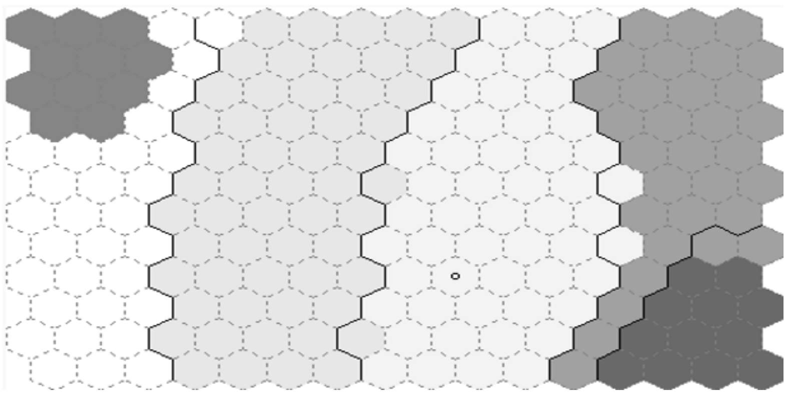

Fig. 3. Non-destructive testing methods input clusters group.

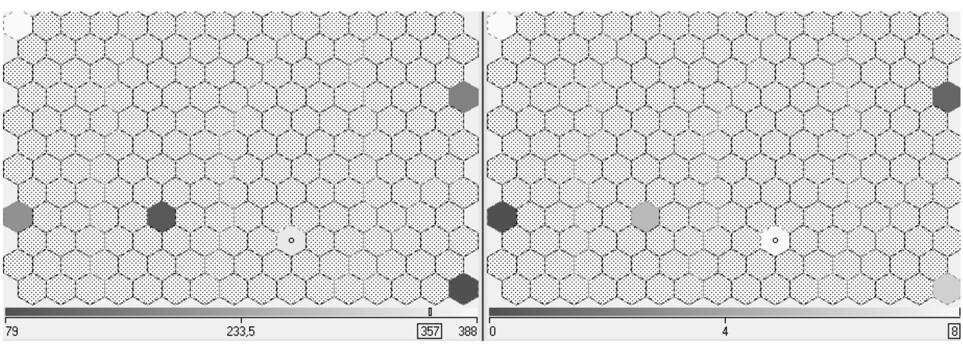

Fig. 4. The data-in for the markets of goods and services input clusters groups.

On the left in the figure– offers for equipment; on the right – offers on services.

The input data on the markets for goods and services are grouped into the following clusters (fig. 4):

The resulting matrix of distances is represented in fig. 5

Table 1. Data for the input values rated on effectiveness scales

Object of control		Type of NFM						
		Electromagnetic (radiation, optical)	**Capillary**	**Eddy current**	**Magnetic**	**Acoustic**	**Thermal**	**Radio wave**
		Non-ferromagnetic materials						
		Wire, in the range of diameter						
1-14 mm		4	0	5	0	5	0	0
0,01-1 mm		4	0	5	0	5	3	0
		Rods, ranging in diameter						
156-1000 mm		5	0	5	0	5	0	0
30-100 mm		5	0	5	0	5	0	0
3-40 mm		5	0	5	0	5	0	0
		Sheets, plates with thickness						
4-10 and more mm		5	4	5	0	5	0	0
0.1-3.9 mm		5	4	5	0	5	0	0
0.1-1 mm		4	4	5	0	5	3	3
Long product		5	4	4	0	5	0	0
Casting		5	5	0	0	4	3	0
Welds		3	4	3	3	5	3	0
Glued joints		4	4	0	0	5	4	5
Soldering joints		3	3	3	0	5	3	0
Threaded joints		0	4	3	5	0	0	0
		Ferromagnetic materials						
Wire		4	0	5	5	5	3	0
		Rods, ranging in diameter						
30-10 mm		5	0	5	5	5	0	0
3-4 mm		5	0	5	5	5	0	0
		Welded tubes with a diameter in the range						
150-1000 mm		4	4	5	5	5	0	0
50-150 mm		4	4	5	5	5	0	0
30-40 mm		4	4	5	5	5	0	0
		Sheets, plates with thickness						
4-10 and more mm		4	4	4	4	5	0	0
0,1-3,9 mm		4	4	5	5	5	0	0
0,1-1 mm		4	4	5	5	5	3	3
Long product		4	4	3	3	5	0	0
Casting		4	4	3	3	4	0	0
Aggregate assessments		103	68	103	58	118	25	6

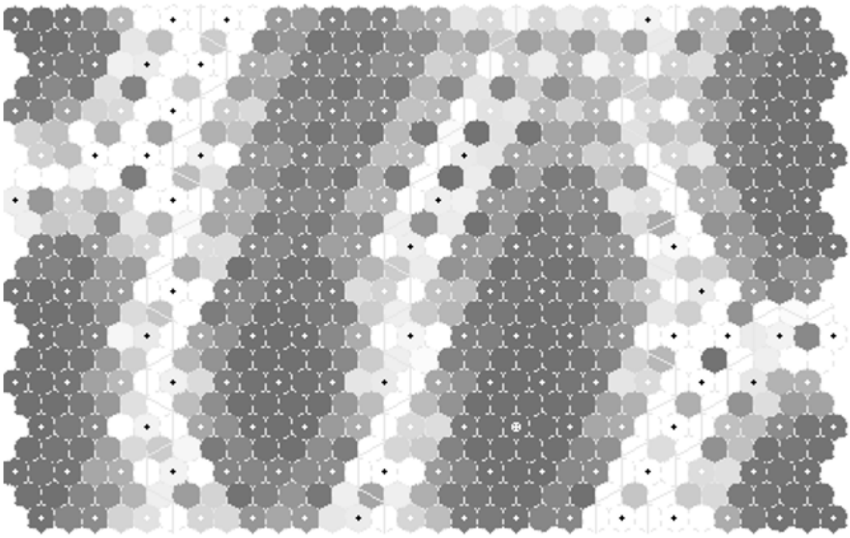

Fig. 5. The result of distance matrix.

As a result of the cluster analysis, based on the distance matrix and the resultant cluster map, the following efficiency diagram of the methods of automated non-destructive testing is formed (fig. 6):

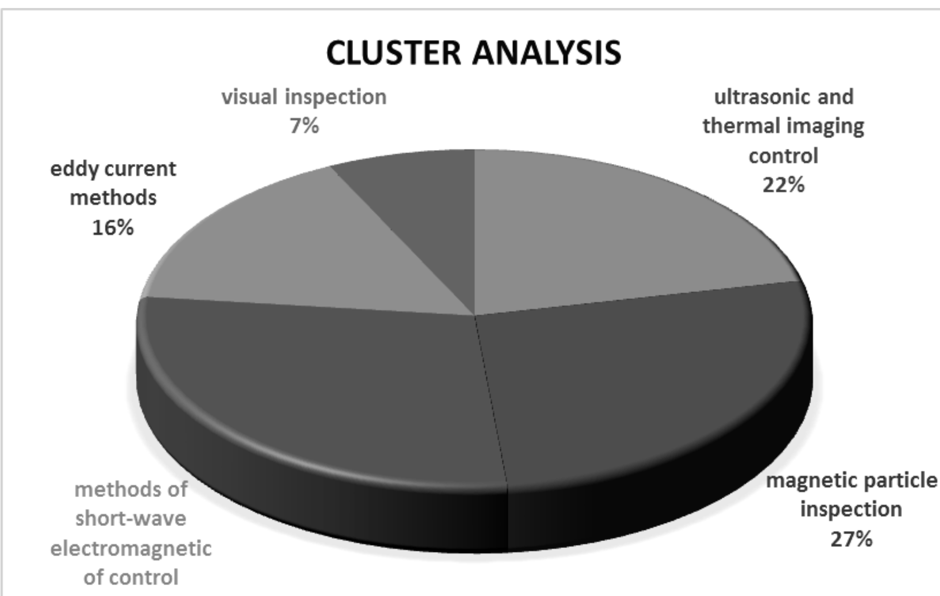

Fig. 6. The result of self-organizing map for nondestructive control.

3 Application of analysis results to the task of spot welds control

When using electromagnetic methods of control, the basis of automation is the recognition of the resulting images (for example - X-rays) in order to develop solutions on the presence or absence of defects.

X-ray diffraction pattern of the welded joint is a two-level classification nugget, the first level is determined which object belongs to a class of disorders cast core diameter, and the second – to classes disorders core arrangement. It was found that for the level of recognition of the violation of the diameter of the cast core, classification can be carried out by building vertical and horizontal histograms for the image segment. For objects that are not included in the "burn" and "unheated" classes, it is necessary to determine the belonging to the displacement classes. In this case, the very fact of classifying the dislocation of the kernel is not very informative, since to remove the defects of the core displacement, it is necessary to know the direction and magnitude of the displacement, which can be determined by creating a group of corresponding classes and determining whether the object belongs to the class of the given group.

When digital processing results in the form of an image, its representation in memory is used in the form of a digital model represented by a matrix of the form:

$$I=\begin{vmatrix} F_{11} & F_{12} & F_{13} & \cdots & F_{1i} & \cdots & F_{1n} \\ F_{21} & F_{22} & F_{23} & \cdots & F_{2i} & \cdots & F_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ F_{j1} & F_{j2} & F_{j3} & \cdots & F_{ji} & \cdots & F_{jn} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ F_{m1} & F_{m2} & F_{m3} & \cdots & F_{mi} & \cdots & F_{mn} \end{vmatrix}, \tag{2}$$

where $F_{i,j}$ – code characterizing the tone, saturation and brightness of the i-th pixel of the j-th line of the raster; $1<i<n$; $1<j<m$.

An important step in the process of preparing a controlled segment to classify by kernel offsets is the selection of edges and contours of objects based on the emphasis on brightness differences [9]. The following methods were studied and tested: Roberts, Laplace, Wallace, Sobel, Kirsch, the statistical method. It is revealed that, with respect to the problem posed, the Laplace method leads to the result, most closely approximated to the required response.

The most suitable for images obtained by X-ray methods (giving the most precise response to the necessary boundaries) is the Laplacian of the following form:

$$L(f(x,y))=-f(x-1,y-1)-2\cdot f(x,y-1)-f(x+1,y-1)-2\cdot f(x-1,y)+12\cdot f(x,y)-2\cdot f(x+1,y)- \\ -f(x-1,y+1)-2\cdot f(x,y+1)-(x+1,y+1) \tag{3}$$

The step of applying patterns to the source segment is an element-wise overlay of all generated templates into the source image based on the prototype comparison. Analyzing the detection of coincidences for all characteristics, the base instance of the class is set by. Based on the detected specimen, the radius and coordinates of the center of the test compound are determined.

According to the received data it is possible to draw conclusions regarding the admissibility of the dimensions of the seat for the connection (to reveal the "defective parts" or "burn" of the part) and the relative location of the previously found center of the cast core of the joint and the center of the weld region, which will allow the possible misalignment of the electrode relative to the surface of the part.

4 Conclusion

In view of the above, one may conclude that leadership in the field of electromagnetic control.

Further lines of research are that the use of short-wavelength electromagnetic nondestructive inspection based on image processing and pattern recognition methods, obtained as a result of the technological process control.

The main drawback of the method of radiation monitoring is that the scattered radiation, depending on the energy of the primary radiation, changes the quality of the image, reduces the contrast and clarity of the image, and, consequently, the sensitivity of the method itself; due to this phenomenon, small-sized defects are difficult to distinguish without the use of automation.

Studied in the field of image processing by such scientists as Basarab M.A., Butakov EA, Wisilter Yu.V., Gulyaev Yu.V., Zheltkov S.Yu., Prince V.A., Nikitov S.A. , Pavlidis T., Pakhomov AA, Potapov AA, Pratt U. Putyatin EP, Salnikov II, Khodarev AN, Huang TS, Yane B., Chen CH [9], Shalkoff RJ [10]. It is established that the algorithms considered by them, despite their speed and partial applicability to the task of automation of nondestructive testing, have not found application in the areas of software image processing for the detection of defects detected by the method of X-ray diffraction of compounds.

This makes it relevant to develop methods for computer image processing within the framework of automated nondestructive testing systems.

References

1. N.Z. Sultanov, E.V. Kostina, M.V. Ovechkin *Automation of management of service devices based on the recognition of graphic data,* Intelligence. Innovation. Investments, Orenburg: "Orenburg State Institute of Management" pp. 65 – 69 (2015)
2. N.P. Aleshin, V.G. Shcherbinsky, *Radiation and magnetic flaw detection of metal products*, 271 p. (1991)
3. Electromagnetic Radiation and Radio Waves [Electronic resource] Access mode : http://www.mpoweruk.com/radio.htm – (date of the application : 01.02.2018).
4. Kohonen, Teuvo, Self-Organized Formation of Topologically Correct Feature Maps. Biological Cybernetics. 43 (1): 59–69. doi:10.1007/bf00337288
5. D. Rutkovskaya, M. Pilinsky, L. Rutkovsky, Neural networks, genetic algorithms and fuzzy systems [trans. from Polish], 452 p. (2008)
6. R. Callan, The Essence of Neural Networks, Williams, 290 p. (2001)
7. Kohonen, T. Self-Organizing Maps (Third Extended Edition), New York, 501 p. (2001)
8. A.A. Potapov, A.A. Pakhomov, S.A. Nikitin, Yu.V. Gulyaev, *The newest methods of image processing*, 496 p. (2008)
9. C.H. Chen, L.F. Rau, Handbook of pattern recognition and computer vision, World Scientific Publishing Co. Pte. Ltd., 984 p. (1995)
10. Shalkoff, R.J, Patrick S. P. Wang. Digital image processing and computer vision, New York : John Wiley & Sons, Inc., 489 p.