UDK 621.382

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INFORMATION TECHNOLOGY OF QUALITY ASSESSMENT OF ASSEMBLY UNITS IN RADIO EQUIPMENT MANUFACTURING

Abstract. *In this paper, an analysis of existing automated test systems (ATS) and corresponding information technologies (IT) of parameters processing was carried out.*

At the heart of the IT and processing methods (identification, segmentation, clustering, classification) is the optimization of the corresponding functional. The analysis showed that for small-scale production the objective function is multimodal and noisy. In gradient processing techniques in such circumstances there is low noise immunity, methods are sensitive to local extreme and the initial search point, in subgradient methods – high error.

To reduce these shortcomings authors proposed methods of identification, classification, clustering, preprocessing and evaluation of product parameters. They are based on the evaluation of the respective functional extremum coordinates using wavelet transform (WT).

The results showed that the proposed methods have improved the clustering quality and classification reliability under a priori uncertainty of diagnostic parameters. On the basis of these methods is proposed to develop the selection of components for the IT equipment in critical applications in radio equipment manufacturing.

Keywords*:* automated systems, classification, *optimization, wavelet-transformation, system of visual information processing*

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ИНФОРМАЦИОННАЯ ТЕХНОЛОГИЯ ОЦЕНКИ КАЧЕСТВА СБОРОЧНЫХ ЕДИНИЦ В РАДИОППАРАТОСТРОЕНИИ

Аннотация. *Разработаны методы слепой деконволюции, классификации, кластеризации, сегментации с поиском оптимума функционалов путем мультистартовой оптимизации с вейвлет-преобразованием. На основе этих методов сформирована информационная технология оценки качества сборочных единиц в радиоаппаратостроении. Результаты исследований показали повышение достоверности диагностирования при низких отношениях сигнал/помеха по мощности и, на ряде этапов повышение быстродействия, что может позволить проводить оценку качества на конвейере технологической линии.*

Ключевые слова*: автоматизированные системы, классификация, оптимизация, вейвлет-преобразование, системы обработки визуальной информации*

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ІНФОРМАЦІЙНА ТЕХНОЛОГІЯ ОЦІНКИ ЯКОСТІ СКЛАДАЛЬНИХ ОДИНИЦЬ

Анотація. *Розроблено методи сліпої деконволюції, класифікації, кластеризації, сегментації з пошуком оптимуму функціоналів шляхом мультістартової оптимізації з вейвлет-перетворенням. На основі цих методів сформована інформаційна технологія оцінки якості збиральних одиниць у радіо апаратобудуванні. Результати досліджень довели підвищення достовірності діагностування при низьких співвідношеннях сигнал/завада по потужності і, на ряді етапів, підвищення швидкодії, що може дозволити проводити оцінку якості на конвеєрі технологічної лінії.*

Ключові слова*: автоматизовані системи, класифікація, оптимізація, вейвлет-перетворення, системи обробки візуальної інформації*

Introduction. For the systems of responsible appointment (car safety, medical diagnostics, etc.) are particularly important workmanship and stability of the parameters during operation [1]. To ensure that condition the automated diagnostic systems (ADS) are used during the production. The improvement of technology, reducing production time, also reduces time to evaluate the stability of components and finished assemblies. Therefore the number of control operations which produce on the conveyor production line is increased [2]. The analysis of existing ADS (with expensive test systems, mechanics and optics) revealed that they use information technology (IT) of parameters processing, which require long-term studies of large batches when changing components or parameters of technological process. And if products are produced in small batches, this amount of research is often not possible, so priori uncertainty of diagnostic parameters grows and accuracy of the diagnosis decreases. Thus, it is actual to develop an IT assessment of the quality of units in radio equipment manufacturing (REM), which will improve the accuracy in the conditions of a priori uncertainty and, in addition, reduce hardware requirements and consequently the requirements for resource intensity and efficiency.

At the heart of the IT and processing methods (filtering, segmentation, clustering, and classification) is optimization of relevant functional. The analysis has shown that for small-scale production the objective function is multimodal and noisy due to the variability of parameters. Processing methods, which are based on the evaluation of the gradient, in such conditions demonstrate low noise immunity, they are sensitive to local extrema and the initial search point and subgradient methods provide high error. To reduce these shortcomings in the works of the authors classification [3], clustering [4], the pre-treatment [5] and evaluation of products parameters [6] methods are proposed. They are based on the evaluation of extremum coordinates for respective functional using wavelet transform (WT). The analysis shows that they have improved quality and reliability of clustering and classification under priori uncertainty of diagnostic parameters. On the basis of these methods it is proposed to develop an IT quality assessment of the assembly units in radio equipment manufacturing.

Formulation of the problem. An important step in the production of security systems and medical equipment is the choice of high-quality and stable external components. To identify potentially unsafe products several approaches were developed. This is production tests that require lengthy and costly research [7 – 8], and IT forecasting helps to reduce this time [7; 9]. The analysis has shown that a significant part of such IT is focused on the prediction value of determining parameter for the particular product (time series [10]). Numerous neural network technologies for multivariate prediction parameters [11] are based on gradient methods and their inherent disadvantages of these methods – the sensitivity to local extrema and the starting point of the search, in some cases – considerable time training the neural network (NN) [7]. Both groups of methods require a large amount of studies [7; 12], which in the production of a rapid change in nomenclature is often impossible to carry out. However, for these applications is sufficient to determine the class of the product by comparing it with the parameters of specification limits [13]. Therefore the well-known Markov model has been chosen for IT [13]. It allows to estimate the parameters of the products based on a relatively small number of measurements.

Description of the technology. It is assumed that N products have k parameters and $x_j(t_1),..., x_j(t_n)$ are the part of a well-known trajectory of product parameters changing over time. They are determined by the accelerated production testing. By using clustering technique with WT [4; 6] groups (clusters) of parameters are identified and in the moment of t_1 n products are separated into r clusters. The number of clusters is selected in accordance with the parameters of the local density in the feature space on the basis of the well-known hypothesis of compactness and extrema search formed considering the objective function [6]. Information technology main stages given below.

1. Determination of informative parameters and carrying out their measurement.

2. By using clustering technique with WT [4; 6] in the moment of t_1 n products are separated into r clusters. Next, the coordinates of their centers $a_i(t)$, $i=1, .. .,r$ are determined [6]. Then distances $R_{ij}(t)$, $i=1, .. ., r, j=1, .. ., n$ to this centers are calculated.

3. For the time t_1 probability matrix $p_{ji}^{(1)} = p_{ji}(t_1)$ is calculated [6; 13]:

$$p_{ji}^{(1)} = \frac{a_j^{(1)}}{R_{ji}^{(1)}}, \quad (1)$$

where the multiplier $a_j^{(1)}$ is defined as:

$$a_j^{(1)} = \left(\sum_{i=1}^{r} \frac{1}{R_{ji}^{(1)}} \right)^{-1}. \quad (2)$$

4. At the moment t_1 each $x_j(t_2)$ is referred to one of the classes from first step. Then new val-

ues of clusters centers $a_i(t_2)$, $i=1,...,r$ and distances $R(x_j(t_2), a_i(t_2),)$ $i=1,..., r$, $j=1,..., n$, for $x_j(t_2)$ are computed. This procedure is performed for all time points.

5. At the s-th step transition probability matrix (1) is modified by the procedures [6]:

– if the point coincides with the center of the cluster, it is considered that the probability for this point to stay in the current cluster is 1, and the probability of transition to a different class is 0;

– if the *j*-th point doesn't coincide with the center of the cluster, transition probabilities are calculated as:

$$p_{ji}^{(s)}=\gamma\left[p_{ji}^{(s-1)}+\left(\frac{1+sign(\Delta R_{ji}^{(s)})}{2}-p_{ji}^{(s-1)}sign(\Delta R_{ji}^{(s)})\right)\Delta\hat{R}_{ji}^{(s)}\right], \quad (3)$$

where $sign(z)=\begin{cases}1, & if\ z\geq 0,\\ -1, & if\ z<0\end{cases}$;

$$\Delta R_{ji}^{(s)}=R_{ji}^{(s-1)}-R_{ji}^{(s)}; \quad (4)$$

$$\Delta\hat{R}_{ji}^{(s)}=\frac{R_{ji}^{(s-1)}-R_{ji}^{(s)}}{R_{ji}^{(s-1)}+R_{ji}^{(s)}}; \quad (5)$$

γ – a scale factor, determined by the normalization of the transition probabilities $\sum_{i=1}^{r}p_{ji}^{s}=1$:

$$\gamma=\frac{1}{1+\left(\frac{1+sign(\Delta R_{ji}^{(s)})}{2}-p_{ji}^{(s-1)}sign(\Delta R_{ji}^{(s)})\right)\Delta\hat{R}_{ji}^{(s)}}. \quad (6)$$

6. Forecast of object belonging is realized according to the constructed transition matrix. For this it is common to use the Bayesian scheme, according to which the object belongs to that class, where $p_{ji0}=\max_{i=1,...r}p_{ji}$ [6; 13].

7. Products from the class with required quality come to the assembly of printed circuit assemblies.

A significant part of ADS in REM with the processing of visual information, determines the coordinates of the defect in the product by comparing its image with the etalon image free from defects. Because of that it is important to combine these images when positioning and it is important to apply the procedures, which can provide the accuracy required for the purposes of processing. Thus, in determining the assemblies of defects, information processing ADS subsystem implements IT for positioning by reference marks (RM) – known marks form on the surface of the product and IT for determination the coordinates and area of defects on them. This IT handles two modes – training mode and operation mode. An important step is the board image filtering to reduce the noise level on it. In low light one of the problems is a blur and the wrong focus. It is important to eliminate these distortions without increasing the cost for the equipment. In automated diagnosis of solder joints by the observed distorted image is required to restore the original without distorting information about the function. This is problem of blind deconvolution [16]. One of the ways of its solution – adaptive filtering. To adjust the filter coefficients iterative optimization objective function (OF) is performed, which in these applications is often multimodal. Therefore algorithms based on gradient descent [17 – 19], in particular, an algorithm (Constant Modulus Algorithm) [20] may lead to a local minimum [21]. This is due to their sensitivity to the starting point of the search. Because of this the determination of filter coefficients by optimization based on the WT is proposed, with has less dependence on the starting point of the search [5] and has investigated ability to reach a global minimum of the objective function when the traditional algorithm (Constant Modulus Algorithm) converges to a local solution. This allows consider this method for processing distorted and blurred images in various technical applications, particularly for assessing the quality of the IT assembly units.

Further, during localization of the RM, it is necessary to determine their coordinates and trace contours; calculate parameters, signs and train a neural network to classify the RM. The operation mode of the IT is: classification RM of product and combining it with the reference image from the database data ADS.

Information technology of positioning defects implements linearization – to bring the appearance of the product image in such way: track – "0", substrate – "1"; median filtering and determination of origin and the area of defects on printed circuit boards (PCB).

For multiplexed workpieces soldering defects are determined before separating them into individual boards to improve efficiency. The probability of soldering defects larger in integrated circuits (ICs) for their determination are often used separate ADS. For these ADS positioning of IC is performed in two steps – positioning workpiece with RM and determination of coordinates on it.

Combining images of IC is produced by the correlation-extreme segmentation based on multistart optimization with WT. This improves combining performance with signal / noise ratio for the target functions greater than 5 in amplitude that may allow diagnosis on the production conveyor line [22].

Conclusions. By using these IT the defect recognition accuracy was 0.85. Immunity was increased to an average of 20 % in comparison with existing systems, which meets practical requirements. Studies have shown that the accuracy of diagnosing products in the range of the signal / noise ratio of 10 ... .20 (by capacity) increased to 1.2 times compare to existing IT ADS. In the range of the signal / noise ratio 7…10 (power) ADS with existing IT is not able to work, and the accuracy of the diagnosis in the application of the developed IT – 0.85. These results may allow the usage of the developed IT in applications that meet specified conditions.

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Received 04.06.2016

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