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G. Shcherbakova, ScD., **V. Krylov**, ScD.,
O. Babilounga, PhD.

METHOD OF CLASSIFICATION WITH TRAINING ON THE WAVELET TRANSFORMATION BASE

Abstract. *The method classification with training on the base of wavelet transformation is designed. This method may be used for identification of the ranges of factors separating surfaces. This method may be used for choice of classification parameters for select ranges of reliability in time of repairing of systems of visual information processing.*

Keywords: *automated systems, classification, optimization, wavelet-transformation, visual information, multi-start optimization, range of coefficient*

Г. Ю. Щербакова, В. Н. Крылов, доктора техн. наук,
О. Ю. Бабилунга, канд. техн. наук

МЕТОД КЛАССИФИКАЦИИ С ОБУЧЕНИЕМ НА БАЗЕ ВЕЙВЛЕТ-ПРЕОБРАЗОВАНИЯ

Аннотация. *Разработан метод классификации с обучением, позволяющий проводить определение диапазонов изменения коэффициентов разделяющих поверхностей с использованием вейвлет-преобразования Метод может быть применен при выборе параметров классификатора с учетом требуемого уровня достоверности на этапе отладки систем обработки визуальной информации.*

Ключевые слова: *автоматизированные системы, классификация, оптимизация, вейвлет-преобразование, визуальная информация, мультистартовая оптимизация, диапазон коэффициента*

Г. Ю. Щербакова, В.М. Крилов, доктора техн. наук,
О. Ю. Бабілунга, канд. техн. наук

МЕТОД КЛАСИФІКАЦІЇ З НАВЧАННЯМ НА БАЗІ ВЕЙВЛЕТ-ПЕРЕТВОРЕННЯ

Анотація. *Розроблено метод класифікації з навчанням, який дозволяє проводити визначення діапазонів зміни коефіцієнтів розділяючих поверхонь з використанням вейвлет-перетворення. Метод може бути використаний при виборі параметрів класифікатора з урахуванням потрібного рівня достовірності на етапі налагодження систем обробки візуальної інформації.*

Ключові слова: *автоматизовані системи, класифікація, оптимізація, вейвлет-перетворення, візуальна інформація, мультістартова оптимізація, діапазон коефіцієнта*

Introduction

In automated systems for visual information processing (ASVIP) in medicine, industry, security systems method of classification mainly determines the accuracy of decisions [1 – 6]. Training in the classification of such systems is often carried out by small sets of parameters, the complex shape of the clusters and their intersection in the feature space [4; 7]. In such systems objects need to recognize invariant to scale, rotation, shift, noised images with distorted shape. It may reduce the reliability [1 – 3; 7]. Trying to increase the accuracy by increasing the dataset for ASVIP leads to increased of resource consumption and reduces the efficiency of systems training with the introduction of new products or processes in the industry, improving medicinal methods in medicine, etc. In such cases in time of training and debugging system there is a need to be able to select a range of parameters of the classifier. Training in the classification allows calculating the coefficients that determine the shape of the surface. This surface separates of the classes in the feature space. The authors have developed a method of classification for ASVIP using wavelet transform (WT), which allow estimate of the point values of these coefficients [7].

In this paper, we propose a method of classification. This classification method can help to determine a set of sub-ranges of coefficient for discriminates surfaces. That to allow the selection of the classifier reliability. Such selection may be required from the perspective of pragmatic adequacy [6]. This method is based on the properties of a WT to conduct spatial processing with adjustable detail.

Objective. In this paper the method of classification with training based on wavelet transform is designed. This method allows defining a set range of values of coefficients discriminates surfaces with using a multi-start optimization on the wavelet transformation (MOWT) base [8].

Defining ranges of the coefficients values of discriminates surfaces in the classification using MOWT

In time of automated classification, for example, in the industrial production, the product must be assigned to one of the classes. The classification is based on the hypothesis of compactness. According to this hypothesis suggests that a class of products similar in value parameters.

In time of classification in this work the minimum of functional $Q(\mathbf{x},\mathbf{c})$ is searched – the sum of errors of the first and second type at vector coefficients $\mathbf{c} = (c_1,\ldots,c_N)$. These coefficients determine the type of surface that separates the classes in the parameter space. In the first stage of classification (for "training") - built surface $y = f(\mathbf{x})$ for separating samples of known classes.

In the second stage (in "operational" mode) – the class of the test product is determined.

The following steps are performed in the first stage (during "training").

Step 1. The training set of parameters $\mathbf{x}$ is formed.

Step 2. The class of surfaces with the property (for two classes A and B) given

$$\operatorname{sign} f(\mathbf{x}) = \begin{cases} 1, \text{ if } \mathbf{x} \in A, \\ -1, \text{ if } \mathbf{x} \in B. \end{cases}$$

Step 3. Functional $Q(\mathbf{x}, \mathbf{c}) = F(y - \hat{f}(\mathbf{x}, \mathbf{c}))$ formulated with $\hat{f}(\mathbf{x}, \mathbf{c}) = \sum_{\nu=1}^{N} c_\nu \varphi_\nu(\mathbf{x})$.

Step 4. Set the parameters of the method MOWT [8] and δ_2 – error in determining the coefficients and $\mathbf{c} = (c_1, \ldots, c_N)$ calculated.

The ranges of separating surfaces coefficients in the work identified by the method of MOWT [8], which is being implemented under the scheme

$$\mathbf{c}[n] = \mathbf{c}[n-1] - \gamma[n] WT_k(\mathbf{Q}(\mathbf{x}[n], \mathbf{c}[n-1])), \quad (1)$$

where $\mathbf{Q}(\mathbf{x}, \mathbf{c})$ – the functional, which depends on the vector of coefficients $\mathbf{c} = (c_1, \ldots, c_N)$ and from $\mathbf{x} = (x_1, \ldots, x_M)$; $\gamma[n]$ – step; n – the number of iterations; k – the number of start;

$$WT_k(\mathbf{Q}(\mathbf{x}[n], \mathbf{c}[n-1])) = \{G_{1k}, G_{2k}, \ldots, G_{Nk}\} \quad (2)$$

– determines the direction of movement to the extreme;

$$G_{jk} = \frac{1}{s_k} \sum_{\substack{i=-\frac{s_k}{2} \\ i \neq 0}}^{\frac{s_k}{2}} Q(\mathbf{x}[n], \mathbf{c}_j + ia) \cdot \Psi_k(i). \quad (3)$$

In (3) s_k – the length of the wavelet function (WF) carrier at the k-th start (s_k – an even number); a – sampling step; $\Psi_k(i)$ – WF at k-th start (Table 1); $j = 1, \ldots, N$ – the dimension of the parameter vector. To assess of the direction in the optimum search (2) selected symmetric and non-stationary wave functions [9], in the first stage - the wave function of the form

$$\Psi_1(i) = \begin{cases} 1, \text{ if } & i = 1, \ldots, \frac{s_1}{2} \\ -1, \text{ if } & i = -1, \ldots, -\frac{s_1}{2} \end{cases}$$

and – in the next stages – WF (Table 1), and on the seventh start

$$\Psi_7(i) = \begin{cases} 1, \text{ if } i = 1, \\ -1, \text{ if } i = -1. \end{cases}$$

1. WF parameters for MOWT

Name	Parameters meaning					
Number of start, k	2	3	4	5	6	7
WF scale, α_k	1	2	3	4	5	–
Carrier length, s_k	20	10	6	4	4	2
Type of function $\Psi_k(i)$	$\begin{cases} \frac{1}{\alpha_k(\lvert i \rvert + 1)}, \\ \text{if } i > 0, \\ -\frac{1}{\alpha_k(\lvert i \rvert + 1)}, \\ \text{if } i < 0, \end{cases}$ $i \in [-\frac{s_k}{2}, +\frac{s_k}{2}]$, $i \neq 0$					$\begin{cases} 1, \\ \text{if } i = 1 \\ -1, \\ \text{if } i = -1 \end{cases}$

Determination of coefficients ranges for separating surfaces held on the base MOWT [8] in the following sequence, with the initial data: $\delta_1, \delta_2, \delta_3$ – error for start, error for the coefficient values, error of ranges coefficients determination at step treatment with WF $\Psi_1(i)$, respectively; k_{max} – the maximum number of starts.

Step 1. There are defined: $c[0]$ – initial approach to coordinate of the optimum; $\gamma[1]$ – step; a form of WT and WF; a – sampling step for WF; s_1 – the length of the carrier WF $\Psi_1(i)$; sk – a step change of the length of carrier for $\Psi_1(i)$ in time of determining the range of coefficients; start number $k = 1$; iteration number $n = 1$.

Step 2. The search direction is estimated on a base of (2) for the start k. When $k = 1$ we used for this WF $\Psi_1(i)$ (in $\mathbf{c}[0]$ – if $n = 1$)). The carrier length s_1 for $\Psi_1(i)$ is determined by the analysis of the objective function. The integrated nature of this WT allows to select a segment of the objective function, which includes (with a high probability) the global optimum, and to determine the range of variation of its coordinates [8; 10 – 11]. The sign checked for (3). Further well-known property of gradient estimation used [12]. This is property of sign changing when passing through the optimum. When the sign is changed, we determine the number of sub-ranges for the coefficients. The maximum range is defined by $k = 1$ with $s = s_1$ – carrier length of WF first start $\Psi_1(i)$, then – with the length of the carrier of $\Psi_1(i)$, varying according to $s = s - sk$. For this purpose, treatment with WF $\Psi_1(i)$ as $\mathbf{c}[n] > \mathbf{c}^* > \mathbf{c}[n-1]$, if $\mathbf{c}[n] > \mathbf{c}[n-1]$ or $\mathbf{c}[n] < \mathbf{c}^* < \mathbf{c}[n-1]$ when $\mathbf{c}[n] < \mathbf{c}[n-1]$ [11].

Step 3. Find the range coefficient is performed by (1) if $k \leq k_{max}$, otherwise – stop.

Step 4. If in the n-th iteration $\lvert \mathbf{c}[n] - \mathbf{c}[n-1] \rvert \leq \delta_1$ is performed, the search ends at the current start, otherwise – $n = n + 1$ and go to step 2.

Step 5. If $k > 1$ and coefficient, which found on k-th start, is different from the result of the $k - 1$ start not more than δ_2 – stop; otherwise, or if $k < k_{max}$ it is, it increases the number of start $k = k + 1$, WF selected for evaluation (2) (at $1 < k < k_{max}$ – WF $\Psi_k(i)$ (Table. 1)), with $k = k_{max}$ the direction (2) is measured by discrete differentiation (with $\Psi_7(i)$, see. table. 1) and proceeds to step 2.

Determine the range of coefficients performed for two classes of 15 images. I have search functionality minimum for $Q(\mathbf{x}, \mathbf{c})$ – the amount of errors of the first and second type for vector $\mathbf{c} = (c_0, c_1)$. Classes were divided into the two-dimensional feature space by means of $\hat{f}(\mathbf{x}, \mathbf{c}) = c_0 + c_1 x$. In studies were selected step $\gamma = 0{,}3$ and starting length of the carrier WF $\Psi_1(i)$ $s_1 = 18$. When calculating for errors $\delta_i, i = \overline{1{,}3}$ for c_0 was obtained range $c_0 = [-4{,}00, \ldots, 4{,}0083]$, for c_1 to get 7 nested ranges ($\Delta_j c_1$ with $j = \overline{1{,}7}$). Figure 1 shows the result of the division of classes with using $\hat{f}(\mathbf{x}, \mathbf{c}) = -4.0 + \Delta_j c_1 x$ at $\Delta_1 c_1 = [1{,}0,\ 2{,}36]$ (1 in the fig.1), $\Delta_3 c_1 = [1{,}15,\ 2{,}24]$ (2 in the Fig. 1), $\Delta_7 c_1 = [1{,}43,\ 1{,}68]$ (3 in figure 1). Time (timer) to determine the range for c_0 of 0.23 sec, to ranges for c_1 – 13,1 sec.

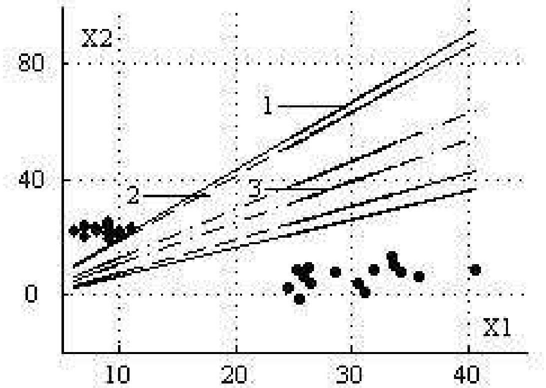

Fig. 1. The result of two class division
$1 - \Delta_1 c_1$; $2 - \Delta_3 c_1$; $3 - \Delta_7 c_1$

Summaries

Thus, the method of classification with training is developed, which allows the determination of a set of sub-band coefficients separating surfaces with using multi-start optimization with WT. Based on the research we concluded that this method can be applied if necessary select the parameters of the classifier to the required level of confidence in the debugging stage for automated systems for visual information processing. This method can be recommended for use in a wide range of applications that meet these conditions.

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Shcherbakova
Galyna Yurievna,
Doctor of science, docent
Professor radio electronics & information technology department Odessa National polytechnic university
Ukraine, Odessa, 65044, Shevchenko Avenue, 1.
E-mail: Galina_onpu@mail.ru

Krylov
Victor Nikolaevich,
Doctor of science, professor
Professor applied mathematics and information technology department Odessa National polytechnic university.
Ukraine, Odessa, 65044, Shevchenko Avenue, 1
E-mail: victor_krylov@inbox.ru

Babilunga
Oxana Uriivna,
Master of science, docent
Docent information systems department Odessa National polytechnic university.
Ukraine, Odessa, 65044, Shevchenko Avenue, 1.
E-mail: babilunga@mail.ru