Increase of estimation accuracy of measure of affinity between objects in the pattern recognition systems

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Abstract— **In this paper problems of increasing of closeness in estimation of measure of affinity between objects for the increase of reliability of pattern recognition in technical vision systems of adaptive robots are considered. Results of carried out theoretical and practical researches for the achievement of stated goal are presented.**

Index Terms— **closeness, measure of affinity between objects, reliability, pattern recognition**

I. INTRODUCTION

All construction of adaptive robots and flexible industrial systems there are problems of perception and recognition both patterns of objects and technological processes with the purpose of development of appropriate control signals depending on a problem to be solved/Their efficiency in many respects depends non reliability of execution of measuring processes, matching of parameters of inspected and standard images and acceptance of the necessary decision by the obtained results about pattern recognition. These processes occur in the presence of the destabilizing factors because of these factors errors in measurement and matching of image parameters take place that creates the defined difficulties in deriving the correct decisions. The accuracy of decision making in pattern recognition in many respects affinity between recognized and standard images, on which decision on a membership of the incoming information ti this or that information set is made [1,2].

II. FORMULATION OF THE PROBLEM

For providing sufficiently high efficiency of adaptive robots performance the requirement to these formulas are formulated as follows.

1. The values of the measures of affinity between objects (MABO) are to be set on a coordinates axes so that the different classes of images essentially differ from each other, i.e. the values of distances between two neighbor classes within one class should be small, but in going to other class they should be large;

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2. The formula should add to the value of a measure of affinity between objects (MABO) an invariance (non sensitivity) to peak or scale variations of attributes values of recognized and standard images, that is very important at time division or spatial separation of measurement processes of recognized and standard images attributes values.

3. The formula should have a possibility of mutual compensation of systematic and random errors arisen at measuring of attributes values recognized and standard objects;

4. The estimation of MABO ought to be carried out with equal or close to equal accuracy for different standard classes with different values of expectation and root mean square deviation.

The analysis of the existing formulas for an estimation of MABO has shown that formulas used for purpose. Manhattan' and Euclidean' formula do not meet these requirements pretty much [3]. In this meaning the most effective formula from the point of view of meeting of above-mentioned requirements is Camberr's distance (1) [1,3]:

$$d = \sum_{i=1}^{n} \left| \frac{x_i - y_i}{x_i + y_i} \right| = \sum_{i=1}^{n} \frac{|A_i|}{|B_i|} \qquad (1)$$

The theoretical analyses of this distance taking into account given requirements have shown the following.

III. THEORY

Let's consider the following implicit model of A measure of affinity between objects [4]:

$$A = F[\, f_x(x; a_1, a_2, a_3, ..., a_m);\; f_y(y; b_1, b_2, b_3, ..., b_m)] \qquad (2)$$

Where $f_x(x; a_1, a_2, a_3, ..., a_m)$ - function of measuring of attribute value of recognized object; $f_y(y; b_1, b_2, b_3, ..., b_m)$ - function of measuring of attribute value of standard object; $a_1, a_2, a_3, ..., a_m$ and $b_1, b_2, b_3, ..., b_m$ - respectively destabilizing factors at measurement of attributes values both recognized and standard objects.

The task of reduction of MABO estimation error is reduced to minimization of influence of the destabilizing factors on a value of parameters last. For this purpose implicit model of MABO is expanded by a Taylor series, and for practical research we'll confine by linear terms:

$$dA = \frac{dF}{df_x} df_x - \frac{dF}{df_x} df_y = \left[\frac{df_x}{dx} dX - \sum_{i=1}^{n} \frac{df_x}{da_i} dX \right] + \left[\frac{df_y}{dy} dY - \sum_{i=1}^{n} \frac{df_y}{db_i} dY \right] \quad (3)$$

In order to be

$$dA = \frac{dF}{df_x} \cdot \frac{df_x}{dx} dX - \frac{dF}{df_y} \cdot \frac{df_y}{dy} dY \quad (4)$$

The following should be obtained:

$$\sum_{i=1}^{n} \frac{df_x}{da_i} da_i + \sum_{i=1}^{n} \frac{df_y}{db_i} db_i = 0 \quad (5)$$

This is generalized condition for invariant image recognition, and for working out of specific procedure of increasing closeness in estimation of Camberr's MABO it is necessary to take into account the distribution laws of measuring errors of parameters of input and standard objects.

Let's assume, that each measured parameters values of recognized and standard objects represented as follows:

$$x_i = x_{i,r} \pm \Delta x_i \quad (6)$$

$$y_i = y_{i,r} \pm \Delta y_i \quad (7)$$

Where $x_{i,r}$ and $y_{i,r}$ - respectively, true parameters values of input and standard objects; Δx_i and Δy_i - accordingly, measuring errors of parameters values of recognized and standard objects with arbitrary forms and characters.

Proceeding from the formula (5) a condition of invariance of value A_i after definite manipulations will be the following expression:

$$\Delta x_i = \Delta y_i \quad (8)$$

$$sign(\Delta x_i) = sign(\Delta y_i) \quad (9)$$

Similarly we can deduce condition of invariance for B_i value:

$$\Delta x_i = \Delta y_i$$

$$sign(\Delta x_i) \neq sign(\Delta y_i) \quad (11)$$

The for the invariance of Z value the following condition deduced:

$$\Delta A_i = \Delta B_i \quad (12)$$

$$sign(\Delta A_i) \neq sign(\Delta B_i) \quad (13)$$

So such a regime can be made when the value of Camberr's measure of affinity will be invariant to destabilizing factors.

In introduced paper the procedure based on increasing of correlation between measuring errors of recognized and standard images parameters by ranking of array elements is offered.

The offered procedure is grounded on practical examination of the theoretically deduced formula for exact estimation of MABO [5]:

$$z = \Phi \sqrt{2(\sigma_x^2 - 2\sigma_x \sigma_y \rho + \sigma_y^2)} + m_x - m_y \quad (14)$$

Where Φ, m_x,m_y and ρ – accordingly, value of the Laplace inverse function, expectations of values of attributes x_i and y_i and coefficient of correlation between errors σ_x and σ_y.

In most cases, there are no possibilities for estimation of expectations of parameters x and y in view of limitation of pattern recognition time or due to fast state changing or position of dynamic objects or processes. In such case estimation of parameters m_x,m_y, Φ^*, σ_x, σ_y and ρ during recognition process of images is hampered. Still it is known, that the parameter Φ^* depends on cost of errors of the first and second sorts, which under a complex formula is approximately defined by parameters values of distributions of measuring errors of attributes values and correlation between them. And as measuring the attributes the value Φ^* can vary in accordance with a drift of measuring errors of images attributes [5,6]. For improving quality of the pattern recognition process investigations on searching methods of rising of correlation between errors and their reduction and also estimation of a value Φ^* are carried out.

IV. The Solution of the Problem

For this purpose the arrays of values $\{x_i\}_{i=1,n}$ and $\{y_i\}_{i=1,n}$ are taken, which are normal distributed values around the values m_x and m_y. In *a* learning mode by multiply measuring of values of attributes of recognized and standard images we estimate parameters m_x,m_y, z, σ_x, σ_y and ρ. After that we're computing Φ^* under the following formula:

$$\Phi^* = \frac{z^* - |m_x - m_y|}{\sqrt{2(\sigma_x^2 - 2\sigma_x \sigma_y \rho + \sigma_y^2)}} \quad (15)$$

Where z* - is more precise value of MABO by one attribute.

In a mode of pattern recognition it is possible take advantage of these parameters and to find a value of MABO by one attribute after one measurement [6].

Therefore, the purpose of introduced paper is: implementation of modes for reaching equalities of errors $\sigma_x = \sigma_y$ and increasing of correlation between them; finding of experimental dependence of the parameter Φ^* from metrological parameter of the equipment and from its current value at pattern recognition; an estimation of precise value of MABO on the basis of the obtained data.

For achievement of invariance of A_i parameter value elements of array $\{x_i\}_{i=1,n}$ and $\{y_i\}_{i=1,n}$ are ranked in increasing order of their values, and a new arrays $\{xx_i\}_{i=1,n}$ and $\{yy_i\}_{i=1,n}$ are formed. On a basis of these arrays elements $\{A_i\}_{i=1,n}$ and $\{B_i\}_{i=1,n}$ are calculated by formula:

$$A_i = xx_i - yy_i \quad (16)$$

$$B_i = xx_i + yy_i \quad (17)$$

Thus, value A_i and B_i become invariant to destabilizing factor. For making z values invariant arrays $\{A_i\}_{i=1,n}$ and $\{B_i\}_{i=1,n}$ are ranked in increasing order of their elements and new arrays $\{AA_i\}_{i=1,n}$ and $\{BB_i\}_{i=1,n}$ are formed, which allow to calculate an invariant value of z:

$$z = \sum_{k=1}^{n} \frac{|AA_k|}{|BB_k|} \quad (18)$$

This method was simulated and positive outcomes were obtained.

Let's analyze these results.

On the basis of simulation data regression models of dependence Φ^* from metrological parameter of at pattern recognition system are created:

$$\Phi^* = 18.085 - 163.949 m_z + 210.485 \cdot |\sigma_x - \sigma_y| - 18.085\rho \quad (19)$$

$$\Phi^* = 18.110 - 220.7984 \cdot |\sigma_x - \sigma_y| - 18.110\rho \quad (20)$$

$$\Phi^* = 0.0597 + 188.87 \cdot |\sigma_x - \sigma_y| \quad (21)$$

The analysis of these models has shown, that most reliable from them is (20).

Thus, on values $|m_x - m_y|$, σ_x, σ_y and ρ it is possible to estimate value Φ^* for further usage at finding of MABO by the following experimental dependence:

$$z = 0.006 + 1.008 m_z + 0.001\Phi^* + 0.2255 \cdot |\sigma_x - \sigma_y| - 0.006\rho \quad (22)$$

Also it is possible to estimate an approximated value $|m_x - m_y|$ by the following model:

$$m_z = -0.0054 + 0.954z - 0.001\Phi^* + 0.213 \cdot |\sigma_x - \sigma_y| + 0.0054\rho \quad (23)$$

Thus, taking into account different metrological parameters of a pattern recognition system it's possible to reduce an error of MABO estimation and to estimate its exact value:

$$\sigma_z = 0.868 + 1.134 \cdot |\sigma_x - \sigma_y| - 0.859\rho \quad (24)$$

V. CONCLUSION

By results of theoretical and experimental examining and on the basis of the analysis of worked out mathematical models it is possible to make the following conclusions:

- Realization of the offered conditions of minimization allows considerably reduce errors of estimation MABO due to matching measuring errors of attributes of recognized and standard images and increasing of correlation between them;
- Not resorting to complex mathematical procedures it is possible to define empirically a Φ^* parameter value and to give the recommendation on choosing the boundary values of decision making on pattern recognition;
- Usage of the offered ways allows in some times to reduce an error of estimation MABO and boost reliability of decision making at pattern recognition;
- Some asymmetry in the formulas is connected to distinction of experiment condition from ideal one and construction of linear regressive models.

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