Increasing the Reliability of Pattern Recognition by Analyzing the Distribution of Errors in Estimating the Measure of Proximity between Objects

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***Abstract.* When recognizing similar or close objects in a report, the accuracy of the recognition is very low when the value of the measure of proximity between objects (MPBO) is close to the value of the error that occurs. modern algorithms are preferred instead of emprig dosturlar to improve accuracy in calculating the measure of proximity between objects. The algorithm proposed in previous research work is not effective, although it eliminates problems such as gross error, correlation coefficient, and the presence of a modular sign in formulas. Proposing a new methodology, range analysis was used instead of summarizing the results when calculating parameter values. The advantage of this system is distinguished by error reduction, more accurate recognition and efficiency. The given algorithm was modeled on a computer and the results were obtained. The processing of the results shows that, thanks to the proposed methodology, it is possible to significantly increase the accuracy of the calculation of the measure of the proximity between objects. At this time, it does not affect the running speed of the system.**

***Keywords:* pattern recognition, measurement errors, interval analysis, correlation coefficient, MPBO, increase of accuracy, re-measurements**

I. INTRODUCTION

Technical vision systems are a field of artificial intelligence that teaches mobile robots to interpret and understand the visual world. Technical vision systems are used in space, aviation, surface ground, water surface and underwater mobile vehicles, which have the ability to analyze the external situation in real time. Technical vision systems have the ability to analyze what they see after accurately identifying and classifying objects using images, videos, and modeled digital images [1–5].

The reliability of the information received by the technical vision system has a significant impact on the formation of the object of recognition in terms of minimizing image recognition errors. The reliability of the information received by technical vision systems that ensure the quality of work of mobile robots are intelligent information-measuring systems is determined primarily by the quality characteristics of the sensors and the parameters of object recognition accuracy. Object recognition accuracy parameters are characterized by the accuracy of estimating the measure of proximity between objects (MPBO) determined by the calculation method. The errors allowed when measuring the values of the features of images, summing up according to the most complex law, create an error in assessing the measure of proximity between objects, which in the computer vision system is commensurate with the actual value of the distance between the features of objects. Therefore, these errors, which reduce the cost of image recognition reliability, seriously impede the use of intelligent information-measurement systems and technical vision systems for the widespread use of mobile robots in various fields.

II. PROBLEM STATEMENT

The accuracy of pattern recognition depends on the accuracy of the calculation of the measure of the proximity between objects. Manhattan, Euclid, Camberra, and many other formulas have been proposed in the field of pattern recognition. They are currently used to calculate the measure of the proximity between objects. However, due to the fact that each formula is overly integrated, there are a number of shortcomings, which maintain the relevance of the correct calculation of the error of

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measurement of proximity between objects and, consequently, the high accuracy of image recognition.

Researches show that it is not possible to eliminate certain random and gross errors using existing empirical formulas. Even increasing the number of repeated measurements does not solve this problem. This is due to the use of an absolute sign in existing formulas (distance can never be negative). In the calculation of the measure of the proximity between objects, a gross error, statistical processing, the presence of a modular sign in the existing formulas and the correlation coefficient between the measurements can be a direct cause of incorrect results. In the proposed methodology, the recognition (input) and exemplary (reference) objects with the help of technical means are entered into the computer. The program method finds in the calculation of the numerical average, the standard deviation, the correlation coefficient and the final error of the measures of the proximity between objects values of the input and reference parameters [6–11].

Using the Manhattan formula, the compatibility of input and reference parameters is checked, so that it is simpler and more convenient than others [12–15]:

$$z = \sum_{i=1}^{n} |x_i - y_i|$$

Here is the result from the i - th re - measurement of input and benchmark parameters according to $\boldsymbol{x_i}$ and $\boldsymbol{y_i}$. When measuring the input and reference parameters, the overage square errors σ_x and σ_y must obey the normal distribution law, so σ_z must obey the normal distribution law. However, the calculation of the absolute price violates the distribution of the final error, and as a result, the average price shifts in a positive direction. Thus, the final result is incorrect. Therefore, in the proposed algorithm, it is necessary to find out what part of this distribution the difference between the input and reference parameters falls on. The difference between the input and reference parameters is $a = x_i - y_j$. x and y are measured in n times, it is usually checked with each value of y for each value of x. That is,

$$\begin{array}{cccc} x_1 - y_1, & x_1 - y_2, & \dots & x_1 - y_n \\ x_2 - y_1, & x_2 - y_2, & \dots & x_2 - y_n \\ \dots & \dots & \dots & \dots \\ x_n - y_1, & x_n - y_2, & \dots & x_n - y_n \end{array}$$

The difference a is checked in the range -3*σ_z - +3*σ_z by every $0.5 \cdot \sigma_z$ steps ([-3*σ_z, -2,5*σ_z], [-2,5*σ_z, -2*σ_z], [-2*σ_z, -1,5*σ_z], [-1,5*σ_z, -σ_z], [-σ_z, -0,5*σ_z], [-0,5*σ_z, 0], [0, 0,5*σ_z], [0,5*σ_z, σ_z], [σ_z,1,5*σ_z], [1,5*σ_z,2*σ_z], [2*σ_z,2,5*σ_z] and [2,5*σ_z,3*σ_z]).

If a does not fall in the interval, the program checks whether it falls in other intervals. In the case of an interval falls, then as the price of $\boldsymbol{a}$, the smallest price of the interval is accepted and sent to the total input and the possible deviations are minimized. In the measurement technique, errors are accepted up to ± 3*σ. Greater than it, is thrown like a gross error. Therefore, a's greater than $-3 \cdot \sigma_z$ and $+3 \cdot \sigma_z$ are not taken into account. Then the a's in the interval $[-3 \cdot \sigma_z, 0]$ and $[0, +3 \cdot \sigma_z]$ are collected and the average value is found by dividing by the number of measurements. The final values are found in the general order by the Manhattan formula and found by the operation of our algorithm. The number of measurements varies from 1 to n. The greater the number of repeated measurements of the input parameters, the greater the accuracy. However, in this case, the speed of the recognition system decreases. Therefore, the number of repeated measurements of the input and reference parameters in the proposed algorithm is taken differently. Since the repeated measurements of the reference parameters are in training mode, their number should be taken as much as possible. Because in this case, the accuracy is high and the speed of the system does not change. Since the identification and reference objects are taken from same in advance, in fact, the result must be "0".

Therefore, the use of interval analysis, taking a relatively small number of repeated measurements, both slows down the operation of the recognition system, and has the appropriate accuracy, which is reflected in this program. It is better to say that the values of *zm* (manhattan) and *zk* (proposed) in the algorithm are closer to the corresponding values obtained at the maximum value of n. Mathematical modeling of the proposed algorithm for calculating the measure of the proximity between objects and the results are given in previous scientific papers. Calculates the current a at the maximum, average, and minimum values of a given range of parameters.

The results are very good when calculating the average value of the current parameter a in a given interval, and the accuracy increases significantly when NK takes repeated measurements. . It also does not affect the processing speed. As can be seen from the given tables and diagrams, the result of the proposed algorithm is much higher than the results obtained by the classical method, and when using the proposed algorithm, the accuracy of the technical vision system increases significantly and the operating speed remains at the required level. Then the measurement errors of the Manhattan and the proposed algorithm are calculated by repeating NK times.

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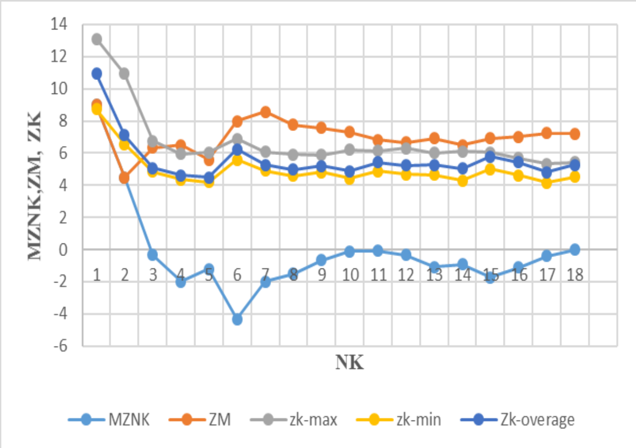

Fig. 1. Comparison of the classical method with the proposed algorithm for calculating the size of the proximity between objects

Fig. 1 is displayed non-modular calculations in blue color, calculations based on Manhattan's formula in red color, take the maximum value of the range instead of the parameters that fall into the range in gray color, take the minimum value of the range instead of the parameters that fall into the range in yellow color and take the average value of the range instead of the parameters that fall into the range in blue-purple color. The graphs show that the proposed algorithm is more accurate than the classical methods.

TABLE I. COMPARISON OF THE CLASSICAL METHOD WITH THE PROPOSED ALGORITHM FOR CALCULATING THE SIZE OF THE PROXIMITY BETWEEN OBJECTS

NK	MZNK	ZM	ZK_{min}	$ZK_{overage}$	ZK_{max}
1	9	9	8,74	10,92	13,11
2	4,5	4,5	6,55	7,1	10,92
3	-0,33	6,33	4,85	5,07	6,74
4	-2	6,5	4,37	4,61	5,94
5	-1,2	5,6	4,19	4,5	6,04
6	-4,33	8	5,58	6,23	6,87
7	-2	8,57	4,91	5,26	6,06
8	-1,5	7,75	4,58	4,96	5,9
9	-0,66	7,55	4,8	5,2	5,88
10	-0,1	7,3	4,42	4,87	6,21
11	-0,09	6,81	4,88	5,42	6,14
12	-0,33	6,67	4,67	5,23	6,29
13	-1,07	6,92	4,66	5,25	6,02
14	-0,93	6,5	4,3	5,05	6,11
15	-1,73	6,93	4,99	5,77	6,03
16	-1,125	7	4,63	5,42	5,68
17	-0,411	7,23	4,17	4,81	5,34
18	0	7,22	4,52	5,27	5,43

In this Table, the number of repeated measurements of the input parameter NK (1-18); MZNK – the manifestation of the Manhattan formula without modular sign; ZM – the measure of the proximity between objects calculated on the basis of Manhattan formula; Zk_{min}, $Zk_{average}$ and ZK_{max} according to which of the measured price falls into any of the ranges, its price is taken as the lower, middle and upper values of the range instead.

As can be seen from the table and figure, the algorithm proposed in all three options has a great advantage. But as it seems, the results are different from each other, and coming to a common opinion creates certain assumptions for the result.

Therefore, another algorithm has been proposed. According to this algorithm, the number of repeated measurements per any range is calculated and the maximum number of repeated measurements per range is decided.

III. PROBLEM SOLVING

Formulas are used in existing systems of recognition of images. However, the error is large because the formulas are too integrated. A new algorithm has been proposed using range analysis to minimize errors.

TABLE II. RESULTS OBTAINED FROM RANGE ANALYSIS WHEN CALCULATING THE MEASURE OF THE PROXIMITY BETWEEN OBJECTS

NK	MK	ZM	OAYÖ	K_max
2	18	4,5	1,9	2
3	18	6,33	1,9	2
4	18	6,5	1,9	2
5	18	5,6	1,9	2
6	18	8	0	1
7	18	8,57	0	1
8	18	7,75	0	1
9	18	7,55	0	1
10	18	7,3	0	1
11	18	6,81	0	1
12	18	6,66	0	1
13	18	6,92	0	1
14	18	6,5	0	1
15	18	6,93	0	1
16	18	7	0	1
17	18	7,23	0	1
18	18	7,22	0	1

As can be seen from Table II, NK and MK performed repeated measurements to calculate the size of the proximity between the objects and how many times each range fell. K_max indicates the range in which the values of repeated measurements fall more.

Table II shows the number of repeated measurements in each range as a result of interval analysis in the range f (1)-f (11).

The green part indicates the area where the repeated measurements fell the most. As can be seen, the recognition of the input quantity in the values of repeated measurements 2-5 falls into the 2nd interval, in the subsequent values of the number of repeated measurements the recognition falls into the 1st interval.

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TABLE III. THE NUMBER OF MEASUREMENTS PER RANGE IN THE INTERVAL ANALYSIS USED

n	f (1)	f (2)	f (3)	f (4)	f (5)	f (6)
2	3	10	4	1	7	6
3	4	12	8	2	8	9
4	5	17	8	10	12	9
5	6	22	8	17	16	9
6	20	13	13	18	12	9
7	25	16	13	20	16	9
8	26	23	18	22	18	9
9	31	26	18	24	22	9
10	36	27	21	28	26	10
11	40	31	21	29	30	11
12	45	32	25	35	31	11
13	48	33	29	37	31	15
14	53	34	33	43	32	15
15	56	35	37	45	32	19
16	61	38	37	47	36	19
17	65	42	39	51	36	22
18	72	43	40	55	37	23

Continuation of Table 3

n	f (7)	f (8)	f (9)	f (10)	f (11)
2	2	2	0	0	1
3	6	3	0	0	1
4	7	3	0	0	1
5	8	3	0	0	1
6	13	1	0	5	4
7	16	1	0	6	4
8	16	2	0	6	4
9	19	2	0	7	4
10	19	2	0	7	4
11	20	4	0	7	5
12	21	4	0	7	5
13	25	4	0	7	5
14	26	4	0	7	5
15	30	4	0	7	5
16	33	4	0	8	5
17	33	4	1	8	5
18	35	4	1	9	5

IV. CONCLUSION

It should be noted that it is more expedient to use this method instead of the existing formulas in automatic recognition and control systems, as the intended shortcomings are eliminated. Thus, along with the elimination of shortcomings, there are a number of advantages. In this case, the errors caused by statistical processing, correlation coefficient, application of the modulus sign in the formulas and gross error are eliminated, and as a result, accuracy increases. Also, despite the increase in the number of repeated measurements, the speed of the recognition system is not affected. The classical method and the proposed algorithms were modeled on a computer and the results were obtained. As can be seen from the tables and graphs, higher results can be obtained by eliminating the uncertainties in recognition by dividing the range of distribution of measurement errors of the measure of proximity between objects into intervals and analyzing those intervals. Since these algorithms are solved on a computer, it is not more difficult to find the optimal values of the intervals. The processing of the results showed that the proposed algorithm can significantly increase the accuracy of estimating the measure of proximity between objects.

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