Increase the Accuracy of Automated Control for Technical Measurements

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***Abstract*— Multiple measurements plays important role in systems of continuous control. As its result multiple measurements the selections of values containing biases are gained. Such biases by their kind is divided for random and systematical. The last one in their turn also contains different types.**
For refinement of measurement results systematical part of instrumental biases should be avoided. For solving this problem method of process stabilization estimation by dimensionless criteria is offered.
Because of easy mathematical realization such an algorithm may be used for measurement automation and its usage allows to optimize measurement numbers and to lower manufacturing time for production.

***Index Terms*— technical measurement, precision, control automation, consecutive analysis**

I. Introduction

Experiment is an essential part of any scientific research. There is a critical necessity of carrying out experiments consisting a large amounts of single observations. It may be caused, on one hand, by the nature of the process, as probability of some events is ridiculously small. This fact is specially significant for events of subatomic character. On the other hand, necessity of measurement value increment may be caused by demand of meterage accuracy increment in cases of insufficient measuring equipment precision.

Multiple measurements plays significant role in systems of continuous monitoring. Data that such systems collect while working may become basement for systems of active control and adjustment systems after appropriate statistical and mathematical processing.

The results of measurement, obtained while carrying out experiments in engineering and natural sciences almost always characterizes by implicitly expressed and close in range systematical and random parts of bias. It may lead to mismatch of control process, and to decrease of accuracy instead of its increment.

By means of mathematical modeling in papers [1-3] shown that in cases of estimation of general populations or selections that close enough to them optimal way of adjustment depends on distribution law of value being measured. However, it still unknown on practice [4-9]. Moreover, practice works almost always is about processing selections with limited number of measured values. That's why there is a necessity of development method to estimate properties of selections and choose the most similar general population [10].

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II. Modeling of Consecutive Measurement Process

To find the most effected way to estimate properties of selection, a mathematical model of pseudorandom values was generated using Matlab. Each pseudorandom measured value consists of three parts: the first part is a nominal value [11-13], the second part is systematical error [12, 14], which can de described by linear or periodical law, and random part, generated with some distribution law [15, 16].

This paper deals with selection, which systematical part described by linear law of Δsyst = k · ni , where k is linear coefficient and ni is the number of measurement. This means that the process simulated mismatch on each iteration. Random part of each value generated with uniform distributions [17-19].

A. Process Stabilizing Criteria

Each selection may be described with four dimentionless criteria, which show process stabilizing with each next measure. this criteria are:

- criteria of variation of average value

$$T_1(n) = \frac{x(i)_{av} - x(n+1)_{av}}{x(n)_{av}} \quad (1)$$

where n is the current number of measurements, $x(i)$ is the current value of measurable;

- criteria of variation of average value increment

$$T_2(n) = T_1(n) + T_1(n+1) \quad (2)$$

- criteria of variation of standard deviation

$$\mathrm{T}_3(n) = \frac{S(n) - S(n+1)}{S(n)} \quad (3)$$

where $S(n) = \sqrt{\frac{1}{1-n}\sum_{i-1}^{n}(x(i) - x(n)_{av})^2}$ - standard deviation;

- criteria of variation of standard deviation increment

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$$T_4(n) = \frac{D(n) - D(n+1)}{D(n)}, \qquad (4)$$

where $D(n) = x(n)_{av} = \pm t_{av} \frac{S(n)}{\sqrt{n}}$ - dispersion of measured value.

The choice of effective criteria (1)-(4) leads to a reduction in the number of measurements. However, the stabilization of the process for each of the criteria for random samples is not uniform [7, 8]. This necessitates the study of these equations, both independently and jointly, in order to analyze the influence of the characteristics of random processes on their stabilization for each of the criteria.

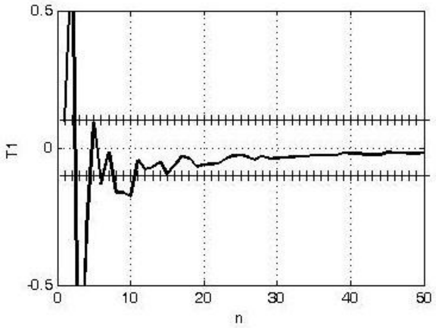
B. Random Process Investigation

Let us consider the case when the sample under study is characterized by a random error [9]. Depending on the requirements for the accuracy of the monitored product, the allowed level of variation in the values of the criteria T_1, T_2, T_3, T_4 is set. The limits of the range can be set symmetrically, or asymmetrically relative to the zero line. Fig. 1 is a graphical representation of the change in the criteria under investigation in a sequential analysis of a sample of 50 pseudo-random numbers in the range from 0 to 10, taken from the uniform distribution law. This sequence of numbers simulates the results of measurements in a real process. On the graphs, you can visually see what number will be necessary to stabilize the process: once the process line stops exceeding the limits of the user-specified interval, the process can be considered stable, and the number N (T_i) following the jump in the process that exceeded the limits of the interval, sufficient. If you take into account all four criteria simultaneously, the result will be more accurate.

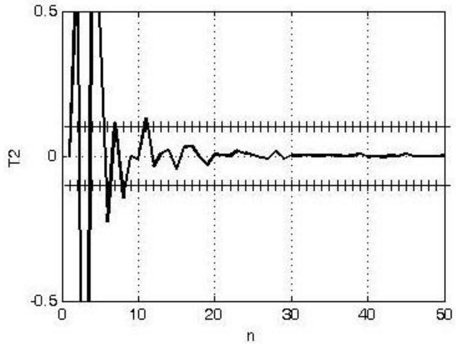
In Table I presents the result of the investigation of various sequences of random numbers generated according to a uniform law, where it can be observed that the fluctuations in the average number necessary for the stabilization of the process are small.

TABLE I. THE MEAN VALUES REQUIRED TO STABILIZE THE PROCESS, WITH DIFFERENT SEQUENCES OF RANDOM NUMBERS

Number of selction	N(T1)	N(T2)	N(T3)	N(T4)
1	8.341	12.822	9.662	10.899
2	8.955	12.850	9.554	10.893
3	8.355	13.028	9.502	10.895
4	8.876	12.951	9.559	10.896
5	8.312	12.873	9.660	10.890



a



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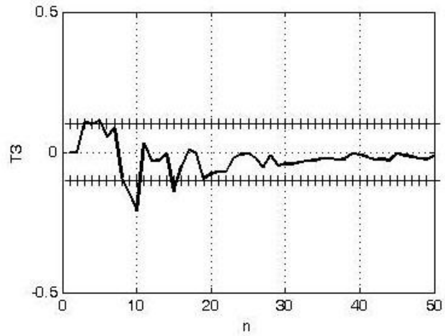

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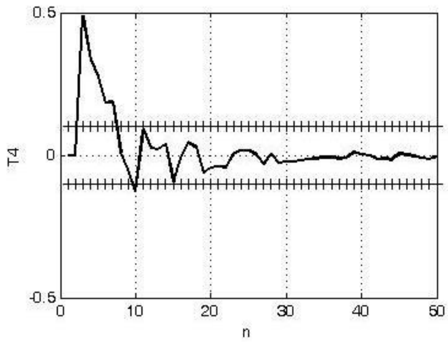

d

Figure 1. - Change in the criteria under investigation in a sequential analysis of a sample of 50 pseudo-random numbers for criteria $a - T_1$, $b - T_2$, c – T_3, d – T_4

Analysis of the results of the mathematical experiment revealed the convergence of solutions for analogous initial data and showed that the optimal number for the stabilization of the process in which there is an exceptionally random error is determined by the criterion T2 of the increment of the mean oscillations.

Further similar experiments were performed for different values of the amplitude (the dimension is identical to the dimension of the measured quantity) of the random error, the results of which are given in Table II.

TABLE II. THE MEAN VALUES REQUIRED FOR STABILIZATION, FOR DIFFERENT AMPLITUDES OF THE RANDOM VARIABLE

Range of random part	$N(T_1)$	$N(T_2)$	$N(T_3)$	$N(T_4)$
0 – 0.1	8.341	12.822	9.662	10.899
0 – 1	8.340	12.900	9.670	10.879
0 – 2	8.370	12.827	9.597	10.896
0 – 25	8.341	12.987	9.477	10.887
0 – 100	8.350	12.885	9.779	10.915

When comparing the data in Table I and II, the average values practically did not change, from which it can be concluded that in the presence of only a random error in the process, the amplitude does not affect the stability of the measurement process. Based on this, we assume that the necessary number of measurements for a sample with a random error is constant. Also, we take the values obtained in Table I for the reference values, which will indicate the presence of only a random error in the process.

C. Systematical Process Investigation

On the basis of the results of the investigation of processes with only a random error, we determine how the processes stabilize with a fraction of the systematic error that varies according to the law $\Delta_{syst} = k \cdot n_i$. To The average number of measurements necessary for the stable observation of processes with random and linear systematic errors is presented in Table III.

TABLE III. THE MEAN VALUES REQUIRED FOR STABILIZATION, FOR VARIOUS SEQUENCES OF RANDOM NUMBERS WITH THE ADDITION OF A SYSTEMATIC ERROR

k	$N(T_1)$	$N(T_2)$	$N(T_3)$	$N(T_4)$
0.5	7.387	8.623	19.238	15.140
1	7.462	7.201	17.599	13.622
2	8.012	6.014	15.504	10.932
10	9.529	4.257	11.554	5.458
30	10.069	3.885	11.032	4.167

According to the data obtained, it can be concluded that the presence of the proportion of systematic error in the process studied indicates an increase in the average sample size by criteria T_3 in comparison with the random component of the error, and the excess of other coefficients, regardless of the coefficient k of the linear component of the systematic error.

III. INVESTIGATION AND IDENTIFICATION OF THE SIMULTANEOUS INFLUENCE OF THE AMPLITUDE OF THE RANDOM COMPONENT

For a sample containing simultaneously random and systematic error components distributed according to a linear law, it can be assumed that only the criterion T_3 determines the required minimum number of measurements. To investigate the proposed assumption of the influence of the criterion T_3 on the number of changes in n, mathematical experiments were additionally carried out, which revealed the simultaneous influence of the amplitude of the random component of the error A and the coefficient k of the linear component of the systematic error, provided there is no systematic component distributed according to the periodic law (Fig. 2)

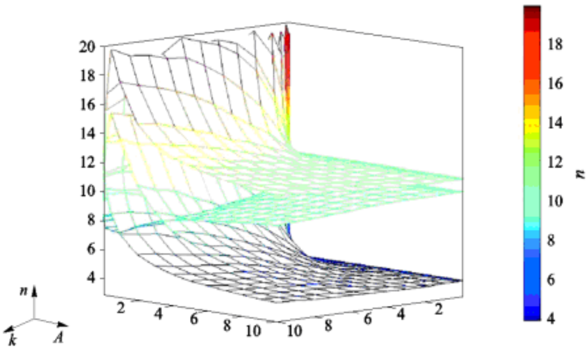

Figure 2. - Dependence of the influence of the range of the random component of the error and the coefficient k of the linear component of the systematic error.

According to the data in Fig. 2 it is evident that the change in the random component of the error at a constant value of the systematic error has an insignificant effect on all four criteria T_1, T_2, T_3, T_4 in a sequential analysis.

The following conclusions can be drawn:

1. In the case when the coefficient k of the linear component of the systematic error substantially exceeds the amplitude A of the oscillations of the random component of the error, the number of measurements required by the successive analysis n is constant and does not depend on the amplitude of the oscillations of the random component of the error.

2. In the case when the amplitude A of the oscillations of the random component of the errors and the coefficient k of the linear component of the systematic error are small quantities of the same order, the number of measurements n is an unstable value, and the extremum can be achieved when the random and systematic deviations are equal.

3. With a significant increase in the proportion of the random component the method of successive analysis shows the convergence of the values of the number of measurements n between the real and random processes.

IV. CONCLUSION

The carried out researches have shown that for the control of product surfaces, the error in the processing of which is determined mainly by random factors, the required minimum number of measurements is a constant independent of the expected accuracy of the measured size.

In the case when the error in machining is caused simultaneously by random and systematic factors, the minimum required number of measurements is a variable. To achieve the greatest accuracy of manufacturing and economic efficiency, this value should be determined directly during the measurement.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

Author Contributions

Maria E. Limorenko conducted the research and analyzed the data.

Arina D. Terenteva improved the mathematical model, wrote an article.

All authors had approved the final version.

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