Data processing of robotic parameters in intelligent robotic systems

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Abstract. The scientific problem of developing the processing of technological data generated by the intelligent robotic systems (IRS) in the mechatronic robotic process is considered. It is shown that mechatronic robotic data is generated simultaneously in the real IRS and in the cloud-based IRS. In the real IRS, data is captured by a system of sensors built into the IRS process chamber. In the cloud-based IRS, mechatronic robotic data is generated by simulating production processes in a modelling tools (in the cloud) using the IRS digital twins. It is shown that the quality of mathematical data processing acceptable for implementation in mechatronic robotic industry is achieved using mathematical methods of regression analysis. Regression analysis allows you to detect the disorder of difficult to control production processes, accompanied by the formation of time series of mechatronic robotic data having a stochastic nature. Structural schemes of the mathematical processing of mechatronic robotic data in industrial IRS is described.

1. Introduction

The design of mechatronic facility is based on design methods that use industrial robotic systems (IRS) as a unit of robotic facility [1, 2]. The IRS performs robotic operations without human resource [3].

In the performing robotic operations in industrial robotic systems, an array of robotic data is generated that characterizes the parameters [4, 5] of the products manufactured in the real IRS robotic chamber and the parameters are generated in the simulation tools involving a cloud-base IRS.

A typical robotic process for manufacturing products corresponds to a time series of robotic data obtained from a system of sensors installed in the chamber of real IRS [6, 7]. According to its statistical properties, the time series of robotic data corresponds to a quasi-stationary random process.

A quasi-stationary random process is a composite process formed by sections with stationary properties that replace each other at an arbitrary point. The moments of the robotic process properties transition from one stationary section to another are determined by the mathematical method and can be planned, due to [8, 9]:

- moving the workpiece, tool, nozzle of the 3D printer or suction cup of the installer of the elements to the next working position within the working areas of the processed details;
• the completion of a given set of robotic operations and the transfer of the unit to the next IRS within the conveyor, etc.,
• and unplanned due to:
• the occurrence of defects in the detail due to the failure of the IRS,
• the use of low-quality multi-metal powder in a 3D printer;
• errors in the software contained in the sets of manual for the leading, for example, to incorrect positioning of the suction cup with the electronic element within the circuit board, etc.

Detection of the moments of transition of the properties of robotic processes performed in IRS is the problem of processing robotic data [10, 11], which provides continuous quality control of products manufactured in IRS. Analysis of robotic processes is based on the use of probabilistic methods and statistical criteria as applied to the processing of time series of robotic data formed in IRS.

2. Robotic data processing in the physical IRS

The real IRS is formed by four basic elements (camera, sensor, drive, controller) [12]. IRS has its own computing resources, concentrated in the controller, and belongs to the category of software controlled industrial robotic systems.

Processing of robotic data in the real IRS is carried out by brainware and components of the IRS, including:
• a mathematical model of the IRS as a closed automatic system;
• a detector is based on the mathematical methods for testing statistical hypotheses;
• a linear forecasting filter, based on the hypothesis about the possibility of statistical forecasting of expected values of robotic data based on the analysis of previously obtained values characterizing the real robotic process in IRS.

The structure scheme of the IRS, processing the robotic data, is shown in figure 1.

![Figure 1. The structure scheme of the IRS, processing the robotic data.](image-url)

The methods for processing robotic data are based on the statistical properties of mechatronic processes (primarily the normal distribution of instantaneous values), which allow approximating robotic data arrays by regression models. Regression models with sufficient accuracy for practice make it possible to represent time series in a parametric space that characterize stationary sections of robotic
processes of various durations. Changes in the properties of the robotic processes of performing mechatronic operations determine the transition in the parametric space of the properties of robotic data from one class of parameters to another. This moment of transition of the properties of robotic data determines the failure of the mechatronic process.

The linear prediction filter allows, based on a sample of limited dimension (no more than 10 samples of robotic data), with a high degree of probability to estimate the expected subsequent value of the measurement results of the parameters of the mechatronic operation. A failure detector compares in real time the results of current measurements of process parameters and expected values. If the mismatch threshold is acceptable for the mismatch of the real and calculated values of robotic data, the state of the mechatronic process is considered nominal. In the event of abnormal deviations, accompanied by the phenomenon of accumulation of error, the mechatronic process is failure and an immediate stop is required.

The threshold for detecting a failure is determined by the type of statistical criteria: minimax, the ideal observer, the Neumann-Pearson, the Bayes, Wald, and others are most widely used in practice. The threshold level is determined by the probabilistic measure of the reliability of the failure detection.

The parameters of the linear prediction filter are determined at the stage of commissioning of mechatronic factory and correspond to one of the typical mechatronic processes. A complete set of parametric settings for linear prediction filters for the entire range of installed at the IRS and all robotic operations implemented in the mechatronic route makes up a library of parameter libraries.

3. Data processing in the cloud IRS

The concept of mechatronic robotic facility implies the existence of cloud copy counterparts of the facilities and its individual intelligent robotic systems. A cloud copy IRS is located in a cloud of mechatronic robotic factory and is a copy of the real IRS [13, 14].

As a component of the IRS copy, a software agent acts, which performs, among others, processing robotic data. Robotic data is generated by modeling the behavior of a real IRS in a simulation tool. The model implementation of robotic data is formed as a result of the mechatronic operation of the processor of robotic operations and is equivalent in its statistical property to measurement data recorded by the sensor system of the real IRS. The diagram of the shaper of the data stream of robotic operations in the cloud IRS is shown in figure 2.

The shaper of the robotic data stream is a line of forming filters, the parameters of each of which are defined in the library of classes of mechatronic processes and correspond to the mechatronic operations of manufacturing products in nominal mode. The temporary implementation of robotic data at the output of the forming filter according to its statistical properties corresponds to robotic data recorded for a given mechatronic process in the IRS.

The mutually exclusive law of key management, providing moments of transition of the process properties from one robotic operation and another, is determined by the algorithm of the mechatronic process of manufacturing the product. Each forming filter is excited in a model tool by the realization of white noise extracted from a random variable generator distributed according to the normal law.

A model implementation of robotic data constitutes a reference implementation in terms of statistical properties formed by sections of stationary time sequences of values, each of which describes a separate robotic operation. Thus, the model implementation is a piecewise-composite time series.

In the case of deviation of the robotic parameters of the products, fixed by the sensors of the real IRS, from the reference values generated in the copy IRS, there is a failure of the mechatronic process performed in the IRS. The deviation of the real and copy IRS parameters is estimated by statistical methods and criteria similar to those placed in the software IRS.

The presence of copy IRS allows the developer of mechatronic robotic facilities to simulate the work of not only individual IRS, but also of entire automatic production sites [15, 16].
4. Conclusion
The reliability of the mathematical processing of robotic data largely depends on the adequacy of statistical models of mechatronic processes to the real data arrays generated during the physical manufacture of products in IRS. A statistical approach to the description of robotic data involves the rejection of the idea of accurately reproducing in the mathematical model the absolute values of the measurement results in favor of models that describe the properties of mechatronic processes.

A homogeneous apparatus can be used to organize production quality control in the real IRS and its copy, which increases the accuracy of data analysis and the convenience of IRS programming, resulting in the formation of similar software modules (libraries of procedures and functions), which increases the degree coincidence of real IRS to its digital counterpart.

Rapid detection of discord in the mechatronic processes is the key to the timely detection of marriage by humanless production methods. The moments of the failure parameters of mechatronic processes should be transferred to a computerized system, upon detection of which are carried out:
- the transfer to real IRS of a job completed with a defective operational IRS;
- zeroing the current production task and disabling the faulty IRS;
- transfer of defective details made with defective materials to the insulator of defects by the resources of the mobile IRS, etc.

The most important problem of organizing the quality control of manufactured products in IRS is the problem of forming a parametric class for the selected type of mathematical models that describe, at the level of statistical properties, all the states of mechatronic processes that are admissible by the robotic route in each IRS. This problem is solved on the basis of mathematical methods with self-learning.

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