



Soviet-era science, translated into English

Reports of the Academy of Sciences of the USSR

N. P. BUSLENKO

1962

SovietRxiv

View the original and related papers at <https://sovietrxiv.org/items/ru-196201.05252>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Abstract

Full Text

Reports of the Academy of Sciences of the USSR
1962. Volume 144, No. 5

CYBERNETICS AND CONTROL THEORY

N. P. BUSLENKO

SIMULATION OF PRODUCTION PROCESSES ON ELECTRONIC DIGITAL MACHINES

(Presented by Academician A. I. Berg on 5 VI 1961)

The study of the production processes of large enterprises, taking into account a wide range of complexly interacting random factors, is of great interest for the design of shops and plants equipped with comprehensive automation, for the development of optimal technological processes, and for solving a number of problems in the organization of production. The information about a process that is necessary for such a study can be obtained by simulating it on general-purpose electronic digital machines.

Preparation for simulation consists of two main stages: 1) constructing a formalized scheme (mathematical model) of the process that is satisfactory from the standpoint of applications, and 2) developing an algorithm that simulates the formalized production process on an electronic digital machine.

The values of the parameters recorded during simulation, obtained from the results of one realization of the process, are random in character. In order to obtain statistically stable estimates for the desired parameters of the production process, multiple simulation is performed and its results are processed accordingly.

This article considers the principles of formalization and construction of simulating algorithms for production processes of the precision manufacture of discrete products. We shall proceed from a production complex (plant, shop, line) that consists of individual elements (machine tools, devices, units) performing production operations on products (semi-finished products, blanks).

When constructing a formalized scheme of a production process (the process of operation of a production complex), it usually proves sufficient to take into account the following principal factors:

1. The random character of the time intervals governing the alternation of various states of the process (the rate at which semi-finished products

are supplied to individual lines, machines, and units; the duration of production operations; the time required to prepare equipment for operation; etc.).

2. The occupancy regime of the elements of the production complex (the arrival of a semi-finished product at an element before the completion of operations on the preceding semi-finished product; the formation of queues of semi-finished products; equipment downtime; etc.).
3. The reliability of the elements of the production complex (equipment failures and breakdowns; regularities associated with the repair of machine tools and units).
4. The regime of tool wear and the gradual withdrawal of equipment from working condition (maladjustment of individual machine tools, units, and the complex as a whole; the procedure for replacing tools and adjusting equipment).
5. The causes of the appearance of defects in the process of manufacturing products.
6. The causes of breakdowns in the production process as a whole or in individual sections.

A mathematical model of a production process constructed with the above factors taken into account makes it possible to investigate the process from the standpoint of evaluating the productivity of the complex and of its individual elements, the quality of the output, the efficiency of equipment utilization, and the optimality of its operating modes.

As a result of modeling, the following indicators characterizing the production process can be determined: the average number of items produced during a specified interval of time (for example, during a shift); the average number of semifinished products processed by each machine tool; the average number of defective items issued by each machine tool for each of the causes giving rise to defects; the average downtime of each element of the production complex for each of the causes producing downtime; the average number of failures and cases in which elements of the production complex leave the operating state; the average number of disruptions of the production process for each of the causes producing them; and so on.

The essence of formalizing typical production processes for the precision manufacture of piece parts reduces to the following.

The state and properties of each semifinished product at any moment of time are described by a certain number of parameters a_1, a_2, \dots, a_n and attributes r_1, r_2, \dots, r_m , which are respectively continuous and discrete (usually integer-valued) random variables. The production process is represented as a sequence of a finite number of operations of the following three types: 1) operations of processing semifinished products, 2) operations of assembling items, and 3) control

operations. By a processing operation we shall understand such an elementary act of the production process on a given semifinished product as a result of which at least one of the parameters or attributes of the semifinished product changes its value. In an assembly operation the participation of at least two semifinished products is assumed: the leading one (the assembly unit) and the dependent ones. As a result of the assembly operation the leading semifinished product changes the value of at least one of its parameters or attributes, while the dependent semifinished products cease to exist. A control operation does not change the values of the parameters or attributes of semifinished products. As a result of control operations, the states or operating modes of the elements of the production complex change.

In view of the fact that the performance of processing or assembly operations may lead to a change in the values of several parameters or attributes of a semifinished product, the division of the process into separate operations is, in the general case, ambiguous. From the standpoint of modeling, it is convenient to represent the process as a sequence of such operations, each of which is performed by one of the actually existing elements of the production complex.

The form of the formalized scheme and the structure of the modeling algorithm are determined to a considerable extent by the construction and nature of the production process. In order to show the principles of formalization and of constructing modeling algorithms, we shall study a typical production process for the manufacture of piece parts. To simulate the action of random factors, we use the techniques for forming realizations of random processes considered in [2].

Let A_i be computational operators, Φ_i operators associated with the formation of realizations of random processes; K_i counters recording the number of items possessing specified properties; and, finally, P_i logical operators. The end of the computations is denoted by the symbol \mathcal{Y} . The notation $P_i^{\uparrow j}$ (or $P_{i \downarrow j}$) means the transfer of control from P_i to operator No. j , under the assumption that the condition tested by P_i is satisfied (not satisfied). We shall denote the transfer of control from operators Nos. l, k, \dots, m to A_i by ${}^{l,k,\dots,m}A_i$.

Suppose that the product is assembled on a conveyor from parts, among which part No. 1 is the leading one, while parts Nos. 2, 3, ..., l are driven. The parts arrive for assembly from l lines (machines), where they are machined. The conveyor moves the leading part in such a way that the i -th assembly operation of the j -th product begins at the time $t_{ij} = t_{1k}$, where

$$k = j + (j - 1)l + i - 1, \quad (1)$$

and t_{1j} are determined by the regime of the production process.

We introduce the following operators: Φ_1 —formation of t_{1j} ; A_2 —their storage; P_3 —comparison $t_{1j} < T$, where T is the duration of the production process; A_4 —processing and output of the simulation results; P_5 —comparison $i < l$; K_6 (K_{66})

–addition of $j + 1$ (respectively $i + 1$); A_7 (A_{76})—formation of $i = 1$ (respectively $i = l$); P_{0i} —the operator replacing the subalgorithm for simulating the i -th assembly operation; K_{1i} —counting the number of products that have passed through the i -th assembly operation; K_{2i} —counting the number of failures of the i -th assembly operation.

Then the enlarged scheme of the algorithm simulating the production process under consideration may be represented in the form

$${}^{66,76}\Phi_1; A_3; P_3^{\uparrow 5}; A_4; ; {}^3P_5^{\uparrow 0i}; K_6; A_7^{5,7}; P_{0i\downarrow 2i}; K_{1i}; K_{66}^1; {}^{0i}K_{2i}; A_{76}^1. \quad (2)$$

To describe the essence of the matter, let us consider in more detail the subalgorithm P_{0i} , which simulates the i -th assembly operation and establishes its connection with the machining operation of the corresponding driven part. We use the following formalization. At the time t_{ij} , inspection begins of a part of the i -th type, which lasts t_{ij}^{pr} . With probability $p^{(\text{br})}$ the part may turn out to be defective. Then it is discarded and replaced by a new one. The assembly duration is $\tau_{ij}^{(\text{sb})}$. If the operation is not completed by the time t_{ij}^* , a failure occurs.

Consider the operators: A_8 —determination of t_{ij} ; A_9 —formation of $\nu = 1$; P_{10} —comparison $n_i > 0$ (n_i is the number of parts of the i -th type); P_{11} —comparison $\nu > 0$; K_{12} —subtraction $n_i - 1$; Φ_{13} —formation of $\tau_{ij}^{(\text{pr})}$; P_{14} —comparison $\xi < p^{(\text{br})}$, where ξ is a random number having a uniform distribution in the interval $(0, 1)$; K_{15} —addition of $r + 1$; Φ_{16} —formation of $\tau_{ij}^{(\text{sb})}$; A_{17} —determination of the moment $t_{ij}^{(\text{k})}$ of completion of the assembly operation; P_{18} (P_{186})—comparison $t_{ij}^{(\text{k})} < t_{ij}^*$ ($t_{ij}^{(\text{n})} < t_{ij}^*$, respectively); Φ_{19} —formation of the parameters of the j -th product after the i -th assembly operation; A_{21} —determination of the moment $t_{ik}^{(\text{n})}$ of the start of machining of the k -th part of the i -th type; K_{23} —addition of $n_i + \nu$; A_{24} —formation of $\nu = 0$. The meanings of the operators A_{20} and A_{22} , as well as the meaning of the index ν , are considered below.

The scheme of the subalgorithm P_{0i} in this case may be written as follows:

$${}^{5,7}A_8; A_9^{9,15,24}P_{10\downarrow 20}; P_{11\downarrow 2i}; K_{12}; \Phi_{13}; P_{14\downarrow 16}; K_{15}^{10,14}\Phi_{16}; \quad (3)$$

$$A_{17}; P_{18\downarrow 2i}; \Phi_{19}^{14}; {}^{10,23}A_{20}; A_{21}; P_{186}^{\uparrow 22}; A_{24}^{10}; {}^{186}A_{22}; K_{23}^{20}.$$

The connection of this subalgorithm with the machining operation for a part of the i -th type is carried out through the operators A_{20} and A_{22} . To reveal their

content, introduce the operators: Φ_{25} —formation of the moment $t_k^{(p)}$ of arrival of the k -th blank (intended for manufacturing a part of the i -th type); P_{26} —comparison $t_k^{(p)} < t^{(g)}$, where $t^{(g)}$ is the moment when the machine is ready for work; P_{27} —comparison $m > 1$ (m is the number of blanks in the queue before the machine); K_{28} (K_{286})—addition of $m + 1$; A_{29} (A_{296})—storage of $t_k^{(p)}$; P_{03} (P_{306})—comparison $m < m^*$ (respectively $m < m^{**}$), where m^* (m^{**}) is the value of m at which the feeding of blanks is stopped (resumed); A_{31} (A_{316})—formation of $\beta = 0$ ($\beta = 1$); A_{32} —transition to processing the next blank; A_{33} (A_{333})—formation of $\nu = 1$ ($\nu = 0$); P_{34} —execution of the processing operation; Φ_{35} —formation of $t^{(r)}$; K_{36} —subtraction of $m - 1$; P_{37} —comparison $\beta > 0$.

Under these assumptions, subalgorithm A_{20} has the form:

$${}^{30, 31, 37}\Phi_{25}; \quad P_{26}^{\uparrow 286}; \quad P_{27\downarrow 32}; \quad K_{28}; \quad A_{29}; \quad {}^{27, 29, 30, 31}A_{33}^{21}; \quad A_{286}; \quad A_{296}; \quad P_{32}^{\uparrow 25}; \quad A_{31}^{32}, \quad (4)$$

and subalgorithm A_{22}

$${}^{186}P_{34}^{\uparrow 33}; \quad A_{336}^{35}; \quad {}^{34}A_{33}; \quad {}^{33, 336}\Phi_{35}; \quad K_{36}; \quad P_{37}^{\uparrow 25}; \quad P_{306\downarrow 32}; \quad A_{31}^{25}. \quad (5)$$

Operator P_{34} models the actual operation of processing a part. We shall proceed from the following formalized scheme of the processing operation. Each blank entering processing is characterized by the parameters α and r . The duration of the operation $\tau_{ik}^{(op)}$ is a random variable whose probabilistic characteristics depend on the parameters α and r , as well as on the time T^* of operation of the machine after adjustment. In the course of operation the machine may fail; the probability of trouble-free operation of the machine is $\mathcal{P}[T^{(ot)}]$; the required repair time $\tau^{(r)}$ is a random variable. If the failure occurred during the processing period of the k -th item, then after repair its processing continues with the finishing time $\tau_{ik}^{(d)}$. Periodic adjustment of the machine is performed when the total time $\Sigma\tau_{ik}^{(op)}$ of its operation reaches \tilde{T} , and lasts $\tau_{ik}^{(n)}$. The probability of obtaining a reject $\tilde{p}^{(br)}$ depends on α , r , and T^* . If a reject is obtained, adjustment of the machine is performed over the time $\bar{\tau}^{(r)}$. At any adjustment of the machine, the quantity $T^{(ot)}$ is recalculated to a new starting point. As a result of carrying out the operation, acceptable items acquire the values of the parameters $\tilde{\alpha}$ and \tilde{r} .

To construct the scheme of the modeling algorithm we shall need the following operators: Φ_{38} —formation of the quantities $\tau^{(op)}$ and $t^{(k)}$ (the moment of completion of the processing operation); Φ_{39} —formation of the nearest moment of failure $t^{(ot)}$ of the machine and $\tau^{(r)}$; P_{40} —comparison $t^{(ot)} < t^{(k)}$; A_{41} —counting $\Sigma\tau^{(op)}$; P_{42} —comparison $\Sigma\tau^{(op)} < \tilde{T}$; Φ_{43} —formation of the time $\tau^{(g)}$ for preparing the machine for operation; A_{44} (A_{446})—determination of $t^{(r)}$; A_{45} —

