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Abstract

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A METHOD OF REPRESENTING THE CONTROL PROCESS IN COMPLEX SYSTEMS

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1. In the present work, human-machine systems are considered, in which the control process proceeds on a real time scale, is carried out discretely with step $\tau = \text{const}$ by means of an electronic computer, and has a finite duration. The human operator monitors the course of the control process and, when the latter deviates from normal, exerts corrective actions on the control algorithm in accordance with the situation. The control process is understood as the transfer of a system into a new state by external action on its parameters ([1]). The control object is understood as a set of automata or machines of any production process.

The most specific feature of the operator's activity in modern automated control systems is that the operator is usually deprived of the possibility of directly observing the controlled objects and uses information that reaches him through communication channels. On the basis of this information a person evaluates the state of the controlled objects and the state of the control processes, makes an appropriate decision, implements it, and after a certain time receives a signal that it has been carried out. Such human activity, which is performed not with real objects but with images imitating them, is called a person' s activity with information models of real objects ([2]).

To create conditions for effective human work in monitoring the control process and correcting it when it deviates from its normal course, it is necessary to present to the operator, in a visual and convenient form, the state of the system and of the control process in dynamics, i.e., at each given moment of time. In addition, the operator must perceive the situation in such a way that the specific task he must solve is clear to him. This is achieved by representing the control process in the form of an integral model ([3]), which allows the operator to perceive the situation as a whole. Below, a method is proposed for constructing an integral model of a special type satisfying these requirements.

2. The control process of a real system is usually divided into a certain number of stages, following one another in a definite order, in each of which some partial objective is achieved. We shall call these stages **control levels**. The operation of the computer control program in passing from the j-th level to the $(j+1)$-st can be carried out in various ways and, generally speaking, requires a different

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

number of steps. Within each step the operation of the program is characterized by the so-called **counting trajectories**. Then the evolution of the counting trajectories reflects the course of the control process. If the counting trajectory remains unchanged, then the control process is at some constant level. When the counting trajectory changes, the process passes to an upper or lower control level. It is natural to proceed to the following visual geometric interpretation of the control process.

Let us call the **control plane** the plane along whose ordinate axis the numbers of the control steps n are plotted, and along whose abscissa axis the numbers of the control levels L_s $(s = 0, 1, 2, \ldots, k)$ are plotted. The beginning of the control process is determined by the instant of time t_n, to which $n = 0$ corresponds. The end of the process is the instant of time t_k $(n = (t_k - t_n)/\tau)$. The control process is represented as the motion of a certain point in the control plane from level to level. Each accounting trajectory belonging to a definite control level is assigned the corresponding number. The numbers of the levels may be placed along the abscissa axis in such a way that the motion of the point proceeds through increasing numbers toward the upper level L_k (Fig. 1). Reaching the level L_k during the time $t_k - t_n$ means that the task has been accomplished by the system. There are methods by means of which it is possible to determine to which of the levels the current accounting trajectory belongs.

Fig. 1

The control plane displayed on an indicator is an integral informational model of the control process (IIMCP).

3. We shall regard as a **normal** control process one that is displayed on the IIMCP as a stepwise increasing function of time, in which each level is reached within a preassigned time interval and the total time of the control process does not exceed the specified value.

The real process may differ from the normal one: it may be displayed on the IIMCP as a nonincreasing function of time (return transitions from a higher level to a lower one are not excluded), and the time required to reach the corresponding level may fall outside the limits defined for the normal control process (Fig. 2).

Fig. 2

Practically for any production process it is possible to determine the time interval for reaching the corresponding level of control, proceeding from the conditions of its normal course. The boundaries of these intervals at each level determine the region of the normal process in the control plane. In the event that the process deviates from the normal one as a result of unforeseen circumstances, the decision on correcting the control program is left to the human operator, in connection with which the problem arises of determining the regions of active interaction between the human operator and the computer in the control process.

In Fig. 2 the following regions are shown:

I –the region of the **normal** control process, in which control is carried out according to the computer program. Correction of the program by the human operator in this region is possible for the purpose of optimization, but is not necessary.

IV–the emergency operating region of the system, in which any human intervention is futile, i.e., in any case the level L_k cannot be reached by the specified time of completion of the process.

III–the region of a probable emergency situation, in which intervention by the human operator is necessary; otherwise the process may pass into the emergency region.

II–the region of a possible emergency situation, in which human intervention is also necessary. Unlike region III, in this case the process proceeds with a margin and may not pass into the emergency region (it is always possible to stop the process, lower the level, or start the process over). However, if the human operator does not make a decision in time, an irreversible process may begin, which is equivalent to transition into the emergency region.

The control levels and the regions of interaction between the human and the computer can be calculated mathematically for a specific system on the basis of statistical data or modeling.

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