FORMULATION OF A CONTROL PROBLEM ON A DISCRETE UNEVEN SCALE UNDER CONDITIONS OF IRREGULAR STOCHASTIC EXTERNAL INFLUENCES

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Abstract: The article presents an approach to the study of the control problem on a discrete uneven time scale under conditions of irregular stochastic external influences. The purpose is a formalized description of the control process of the managed system, which takes into account the monitoring results and provides the opportunity to find optimal mechanisms for influencing the control object. By choosing certain control mechanisms at a particular moment in time, the subject of control expects that the system, under their influence, will enter a certain state at the next moment in time. In addition, it is assumed that the control object periodically receives external influences, the impact of which is extremely difficult to predict. To form a control action, it is necessary to obtain information about the system states. For this purpose, a monitoring system is provided, which at the necessary time takes results about the conditions of the control object. If the decision maker has the opportunity to spend money on all the mechanisms he plans, then the task will be reduced only to finding the minimum required amount of costs for each of these mechanisms. Otherwise, it is necessary to allocate the available funds in such a way that the effectiveness of choosing all the mechanisms would be maximized. As a result, a multi-criteria optimization problem has been formulated, the solution of which will make it possible to form the best control.

Key words: managed system, formal description, stochastic impacts, cost allocation, impact mechanisms.

1. INTRODUCTION

The object of research in this paper is the organizational system of a certain large enterprise (company). The goal is a formal description of the control process, which makes it possible to further solve the corresponding optimization problem. Currently, this task has been studied in depth.

However, not all problems in this area can be considered solved. In particular, in real organizational systems, unplanned environmental impacts periodically occur, which can seriously affect the functioning of the managed facility. These can be various external economic situations (for example, changes in the dollar exchange rate, inflation, accounting policy, etc.), the emergence of competitors, changes in the composition of counterparties, etc. In this regard, it is necessary to formalize the control process of the company's organizational system in these conditions.

2. THE PROBLEM STATUS

The process of managing organizational structures is generally a well-studied task. In [1], the problems of managing organizational systems are described in detail, the basic control mechanisms such as incentive mechanisms, planning, formation of optimal management structures, etc. are investigated. In [2], models of analysis and synthesis of various organizational structures are investigated. In [3], the issue of incentives as one of the most important tools for managing organizational systems is discussed in detail. The basic incentive systems, models of individual and collective incentives, as well as control of the composition of organizational systems are presented.

In general, analyzing the existing approaches to controlled organizational systems, it should be noted that in the analyzed works, much attention is paid to the incentive mechanism and planning. At the same time, it is necessary to note external accidental influences, the influence of which can significantly change the behavior of the studied control object.

3. RESEARCH PROGRESS

The task can be formulated as follows. Suppose there is some kind of controlled organizational system. We will investigate the process of controlling it at discrete time points t_1, t_2, ..., t_n,… [4]. Strictly speaking, these values can have a different spread on the time axis (in other words, the control action can be carried out unevenly). Let's assume that it is possible in some way to fix the results of the operation of the system under study at time t_{k+1}:

$$R\left(t_{k+1}\right)=\left(R_1\left(t_{k+1}\right),R_2\left(t_{k+1}\right),...,R_N\left(t_{k+1}\right)\right). \tag{1}$$

This result is obtained as a result of the control of this system. It can be said that these states characterize the process of functioning of the object under study to one degree or another. The purpose of the object's operation is a certain result (most often, a material one), which will be reflected by the Res resource vector:

$$Res\left(t_{k+1}\right)=\left(Res_1\left(t_{k+1}\right),Res_2\left(t_{k+1}\right),...,Res_M\left(t_{k+1}\right)\right). \tag{2}$$

In general, control should include efficient allocation of resources to obtain the desired state of the control object. We describe the control in the form of a vector, each element of which represents a numerical value of some effect directed at the object under study:

$$C(t_{k+1}) = (C_1(t_{k+1}), C_2(t_{k+1}), ..., C_N(t_{k+1})). \tag{3}$$

This vector will also depend on time, since the impacts will be different at different points in time. In addition, it will depend on resources (RES), which will come directly or indirectly.

However, first of all, this impact will depend on the performance of the system. Let us denote by F a certain function that "transforms", according to the subject of control, the results (1) into the chosen control strategies (3) [5].

Let's explain what "according to the subject of control" means in this context. By choosing certain control mechanisms at time t_k, the subject of control expects that the system will switch to certain states under their influence at time t_{k+1}.

$$S(t_{k+1}) = (S_1(t_{k+1}), S_2(t_{k+1}), ..., S_N(t_{k+1})). \tag{4}$$

In fact, at time tk+1, the control object was in a state that is described by formula (1). The main reason for this misalignment is the incorrect choice of exposure to the control object. However, another possible reason for this may be due to the limited set of control actions of the control object [6]. Another reason may be due to the fact that the impact is formed based on the information that is obtained using some kind of data collection and processing system. However, for one reason or another, misalignment is also possible here. In other words, the results that actually characterize the system and are determined by formula (1) may differ to some extent from the data that the control entity receives and uses to make decisions (3).

4. CONTROL AND MONITORING POINTS

Denote by

$$\tilde{R}(t_{k+1}) = (\tilde{R}_1(t_{k+1}), \tilde{R}_2(t_{k+1}), ..., \tilde{R}_N(t_{k+1})). \tag{5}$$

data on the results of the system's operation, which are received by the decision maker (DM). Then we can state that

$$C(t_{k+1}) = F_1(\tilde{R}(t_k)). \tag{6}$$

Formula (5) explains that the control of an organizational system at time t_{l+1} represents some impact, depending on the data on the functioning of the control object that the control system received at time t_k. At the same time, the subject of control expects that the system under this influence will enter the state described by (1).

Let's also assume that at some random points in time (which, generally speaking, are random and do not coincide with t_1, t_2, ...), some random effects on the system may occur [7], which may significantly affect its states. Thus:

$$R(t) = F_2(\tilde{R}(t_k), \xi(t)), t_k < t < t_{k+1}. \tag{7}$$

Here, □(t) is some random action that occurred at a random moment in time t, which, generally speaking, does not coincide with the time points at which the control action was planned. Let's also assume that this external impact is poorly predictable. This means that it is extremely difficult to predict this external factor in advance and respond to it with proactive control. Schematically, the control process can be represented in Figure 1.

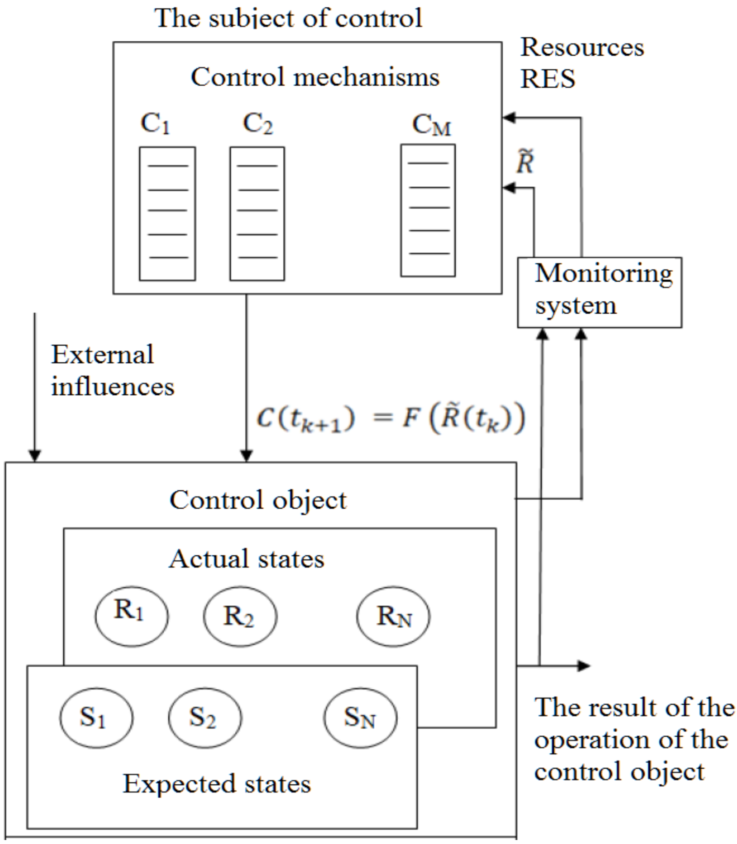

Figure 1. The system control process scheme

Let's explain the basic notation. As you can see, the system consists of an object and a subject of control. The subject of control can make some decisions described by formula (6). These decisions directly affect the states of R in which the control object is currently located. However, in some cases, the actual conditions do not match those expected by the control entity. This is primarily due to the fact that the actual states depend on specific performers, whose behaviour is difficult to predict. In addition, it is assumed that the control object periodically receives external influences, the impact of which is extremely difficult to predict. To form a control action, it is necessary to obtain information about the system states. For this purpose, a monitoring system (SM) is provided, which records the results on the conditions of the control object at the necessary time.

5. THE MAIN TASK OF CONTROL

Let's formulate the main task that needs to be solved for the DM. Let's assume that the subject of control has preferences about what the results of the work of the control object should be. In particular, let there be a number of results $R_1, R_2, ..., R_m$, which it is advisable to aim at the limiting value:

$$\begin{cases} R_1(t_k) \to \max(\min); \\ R_2(t_k) \to \max(\min); \\ \dots \\ R_m(t_k) \to \max(\min). \end{cases} \tag{8}$$

For other indicators, it is only important to comply with certain restrictions. Let them be defined as follows:

$$V = \left(V_{m+1}, \dots, V_N\right). \tag{9}$$

In (9), these results are represented by constants, although in general they may change over time. This is done in order to note that these results, if they change, will occur much less frequently than the formation of impacts on the control object. Then the constraints can be formalized as follows:

$$\begin{cases} R_{m+1}(t_k) \le V_{m+1}; \\ \dots \\ R_{m+l}(t_k) \le V_{m+l}; \\ R_{m+l+1}(t_k) \ge V_{m+l+1}; \\ \dots \\ R_N(t_k) \ge V_N. \end{cases} \tag{10}$$

Then the task of managing an organizational system can be defined as finding such an impact F, in which the results of the functioning of the control object will meet the goals (8) under conditions (10).

In addition, it is necessary to minimize misalignment at each stage of control. In particular, it is necessary to minimize the following values:

$$\left\| R\left(t_k\right) - \tilde{R}\left(t_k\right) \right\| \to \min. \tag{11}$$

In addition, it is advisable to minimize misalignment:

$$\left\| R\left(t_k\right) - S\left(t_k\right) \right\| \to \min. \tag{12}$$

In (11) and (12), the sign $\|\cdot\|$ indicates the norm and can be calculated in different ways. In particular, the ratio (11), for example, can turn into the following system:

$$\begin{cases} \left| R_1\left(t_k\right) - \tilde{R}_1\left(t_k\right) \right| \to \min; \\ \left| R_2\left(t_k\right) - \tilde{R}_2\left(t_k\right) \right| \to \min; \\ \dots \\ \left| R_N\left(t_k\right) - \tilde{R}_N\left(t_k\right) \right| \to \min. \end{cases} \tag{13}$$

6. THE COMPLEXITIES OF THE CONTROL PROCESS

Let's consider the main problems that arise when managing the systems under study. The main problem is the discrepancy between states (1) and (4). This problem arises, as noted above, due to the inability to predict the behavior of individual participants in the control object (their behavior can be predicted only in a statistical sense). In addition, a distinctive feature of the system under study is the possible external accidental impact. In some cases, it can be partially predicted or predicted (for example, a change of a counterparty, the appearance of a competitor, etc.). However, some accidental impacts can occur suddenly and have quite a serious resonance. Thus, in order to reduce the negative effects of accidental environmental influences, it is necessary to have two forecasting subsystems.:

- a subsystem for forecasting external impacts, which, based on statistical information and information coming from outside, would be able to predict the occurrence of a particular impact.;
- subsystems for predicting the reaction of individual participants in the studied object to control mechanisms (and, possibly, to planned external influences).

The presence of such a forecasting subsystem will help to minimize overall (12).

In order to achieve the minima in formula (13), it is necessary to develop a monitoring system [8] that would meet the following requirements:

- operational data collection at all levels of the hierarchy of the organizational system;
- data preparation and processing;
- storage of incoming data for the purpose of their further analysis;
- analysis of the results obtained (operational reporting).

In addition, the monitoring system may include a decision support system that makes it possible to recommend certain control actions based on the data obtained.

The generalized algorithm of the monitoring system will be as follows:

- get standards from the LPR to measure the necessary characteristics;
- collect information about the result of the operation of the control object at the time t;
- process the collected results, obtain some quantitative indicators of the functioning of the control facility;
- compare the results and standards;
- to draw a conclusion about the functioning of the control object and, possibly, to offer recommendations on the development of control decisions.

7. CONCLUSION

When designing a monitoring system, it is necessary to determine:

- objects of control;
- the regulatory framework;
- mechanisms and methods of tracking;
- data processing mechanisms.

Next, we will consider various options for choosing control mechanisms. Note that the use of each of these mechanisms requires the investment of a certain amount of resources (money). This may be, for example, financial incentives for performers, replacement of equipment with better ones, etc. Any such action will require certain costs from the manager. If the DM has the opportunity to spend funds on all the mechanisms it plans, then the task will be limited only to finding the minimum required amount of costs for each of these mechanisms. Otherwise, it is necessary to allocate the available funds in such a way that the effectiveness of choosing all the mechanisms would be maximized.

Thus, a formalization of the system control process is proposed, which differs by taking into account random influences. The individual subtasks allowing to provide effective control of an organizational system are investigated, the main approaches to their solution are offered.

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