MODELING OF ORGANIZATIONS

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Contents

Summary

The state-of-the-art and the outlooks for the development of organization models within the framework of scientific areas such as the active system theory, theory of hierarchical games, theory of contracts, and implementation theory are outlined. A model of the active system is introduced, and the problem of control is discussed in general terms. A system of classifications of the problems of organization control is introduced, and listed are the basic mechanisms of control of the active systems and their application fields.

1. Introduction

In the context of rapidly developing mathematical control theory and intensive introduction of its results into design of new and upgrading of the existing technical systems, in the late 1960's numerous research institutions actually simultaneously made attempts to apply the general approaches of the control theory to develop mathematical models of the social and economic systems. A specific characteristic of the socio-economic systems lies in the fact that, in contrast to the technical systems, their components (person, team, collective, and so on) demonstrate activity, that is, ability to act purposefully or, stated differently, to take actions according to their own preferences and interests. For example, the individual can, if it is beneficial to him/her, to reveal information that contradict the actual state of affairs or can deliberately fail to fulfill the plans – again, if this corresponds to his/her interests, and so on.

Consequently, one needs to choose control actions with regard for the possible responses of the controlled subjects and apply those decision making mechanisms which take into account and coordinate the interests of the controlling organ (the principal) and the controlled subjects (agents) most of all. It has become clear today that sustainable development of the large-scale systems is possible only if adequate effective mechanisms of organization control are used (see *System Analysis and Global Sustainable Development*).

The frame of organization control problems where these mechanisms are used is extremely wide and ranges from process control to decision making at the regional and national levels. One can cite by way of examples the procedures for estimation of the activity of structural subdivisions, motivation (incentive) mechanisms inducing the agents to choose certain actions in the interests of the principal; procedures for allocation of the material and financial resources on the basis of information about the efficiency of their use as presented by the claimants, and so on (see for detail what follows).

The active system theory is one of the lines of research which takes into account purposeful behavior of the participants of a socio-economic (active) system. This theory was originated and is actively developed within the precincts of the Institute of Control Sciences (former Institute of Automation and Remote Control) of the Russian Academy of Sciences.

The active system theory is a division of the theory of control of the socio-economic systems which considers the properties of the mechanisms of their operation which are due to the manifestations of the participants' activity. Mathematical (game-theoretic) modeling and simulation are the main tools of studies. In terms of the approaches and methods used, the active system theory is affiliated to the divisions of the theory of control of socio-economic systems such as the theory of implementation theory, and so on.

2. Model of the Active System and General Formulation of the Control Problem

Let us consider the problem of control of a passive or active system. Let the *system state* be described by the variable $y \in A$ belonging to the feasible set A formed by resource and objective constrains of the model. The system state depends on the *control actions* $u \in U : y = F(u)$. Let us assume that the functional $\Phi(u, y)$ defining *efficiency of system operation* is defined on the set $U \times A$. The value $K(u) = \Phi(u, F(u))$ is called the *efficiency of control* $u \in U$. Then, the problem of the controlling organ is to choose a feasible control $u^* \in U$ such that its efficiency is maximum, provided that the system response $F(u)$ to the control actions $u^* = \arg \max_{u \in U} K(u)$ is known.

Let us discuss the differences between the models of control of the passive and active systems. For the *passive* (technical, formal, and so on) *system*, the dependence $y = F(u)$ is in fact a model of the system (controlled object) which reflects the laws and limitations of its operation. For example, for the dynamic system this dependence may be the solution of a system of differential equations (see *Differential Equation Models*), for a "black box" – the result of experiments, and so on. All passive systems are characterized by "determinism" of control – not in the sense that there is no uncertainty, but in the sense that the controlled object has no freedom in choosing its state and no possibility to predict the behavior of the controlling organ.

This is not the case in the *active systems,* that is, those where the controlled subjects (more precisely, at least one subject) are active and can choose their actions. In addition to being able to choose their states, the elements of the *active systems* have their own interests and preferences, that is, make purposeful choice – otherwise, their behavior could be regarded as passive. The system model $F(\cdot)$ which must take into account the manifestations of activity of the controlled subjects is specified correspondingly. These manifestations are described as follows: it is assumed that the controlled subjects strive to the states that are the best under the given control actions in terms of their preferences and the control actions depend in turn on the states of the controlled subjects. Ability of the controlled subjects to "predict" – within the framework of the information available – the behavior of the controlling organ, that is, its response to the system state, and so on, is one of the main manifestations of their activity.

If the controlling organ has a model of the active system which adequately describes its behavior, then the *problem of control* (design of the optimal controlling action) comes to the aforementioned problem of choosing the optimal control $u^* \in U$, that is, the feasible control maximizing the efficiency.

3. Classification of the Control Mechanisms

From the standpoint of system analysis, any system is defined by listing its *composition*, *structure*, *and functions*. With regard for purposeful behavior of the participants of the active system, their functions are described within the framework of the decision making models. Any such model includes at least the set of choice alternatives, the preferences of the subject that carries out this choice, and information available to it. The model of *organization* (*active system*), therefore, is defined by setting

- *composition* of system participants, that is, its elements;
- *structure*, that is, the totality of the informational, control, technological, and other relations between the system participants;

- *sets of feasible strategies* of the system participants which reflect, among others, the institutional, technological, and other constraints and norms of their joint activity;
- *preferences* of the system participants;
- *awareness*, the information about the essential parameters that is available to the system participants at the time of making decisions about the strategies;
- *order of operation*, that is, the sequence of obtaining information and choosing the strategy by the participants of the active system.

The composition defines “who” is included in the system; the structure – “who interacts with whom” (from this standpoint, the order of operation is closely related with the system structure because the former defines the cause-and-effect relations and the order of interaction), the feasible sets – “who can what,” the goal functions – “who wants what,” and awareness – “who knows what.”

Control of the active system, which is understood as the action on the controlled system with the aim of providing its desired behavior, can affect any of the above six model features.

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Biographical Sketches

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