Consideration of an Ecosystem From the Standpoint of Theory and Practice of Managing Production Systems

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Abstract. In this article, the ecosystem is considered from the point of view of the control object. The mechanism of analysis of an ecosystem as a product of manufacturing process has been applied. The main elements that are necessary for the control system are considered. A theoretical model of the ecosystem management system has been developed. This system is aimed at making an expert assessment of a natural object as an object of nature management.

1. Introduction

We can probably consider that the main critical threats to the survival of the mankind are the threat of mutual destruction, global climate change and anthropogenic degradation of habitats. All of these will make life on Earth barely possible at all. First, we can describe the pessimistic scenarios. People are armed with increasingly powerful means of influencing nature and themselves. The cost of their mistakes consistently increases. Humanity can launch a catastrophic self-destruction mechanism. This phenomenon could become unmanageable.

Many people know sad history of the Aral Sea. Once it was the fourth largest inland water reservoir in the world. Its area was 67,300 square kilometers. This sea was surrounded on all sides by prosperous cities. Their population was engaged in sheep-breeding and fisheries. Forty thousand jobs were involved in this production. The sea supplied the former Soviet Union with a large quantities of fish. The Aral Sea was originally fed by large rivers. Amu Darya is in the south, while Syr Darya is in the north. The first was considered the longest river in the region. It was running for 2414 kilometers in the steppe. But in the 1960s, the Soviets decided to change this. They thought they could make the steppe a flourishing and prosperous area. To do this, they built huge irrigation systems. They dug channels with a total length of 30 thousand kilometers, 45 dams, and over 80 reservoirs. The water system was used to irrigate endless cotton and wheat fields of Kazakhstan and Uzbekistan. The system proved to be faulty and inefficient. As a result, the Amu Darya lost most of its water. The river could not reach the Aral Sea. Today its waters end about 110 kilometers from the sea. The inner sea began to decrease rapidly in size. After several decades, it turned into a handful of small lakes. Current size of the Aral Sea reaches only one-tenth of its historical size.
2. The relevance of research
We offer a management system for a natural object considered as a technological process. Let us imagine management as a relationship between the subject and the object. Humans are the subject of control (who controls). The rest of the natural environment is the object of control (what the subject controls). We will describe the functioning of the ecosystem as a management system. Further, we apply the control theory to it.
Cybernetics defines management as the functioning of a "management system". It includes a regulator (subject of control), an object of control and a feedback. Feedback provides information about the current state of the control object to the controller. The controller compares the current state of the control object with the desired one. If a deviation is detected, the regulator generates a control effect on the control object.

3. Theoretical part
At present, the task of the ecosystem management is becoming still more and more urgent. This task can be solved by introducing a real object in the information model. In this model, interactions between abiotic and biotic objects must be presented. The model should be adequate. The state of the ecosystem object is described by the vector of indicators. The factors that change this state can be classified in four categories:
- Controlled impacts
- Uncontrolled measurable impacts
- Uncontrolled unmeasurable impacts
- Noise that cannot be determined or measured.

The unknown factors must be detected, for example, by conducting a cluster analysis or analyzing the polymodality of empirical distributions.

We started the solution of the control problem with the representation of the managed ecosystem in the control system with feedback (Figure 1). Note that the current state of the ecosystem is determined by the vector of measurable indicators (those that can be measured directly by instruments or evaluated by expert methods). The control effect on the ecosystem is formed on the basis of the analyzed indicators, the value of which can be determined on the basis of individual measurements. Similarly, the desired state of the ecosystem is formed on the basis of analyzed indicators. Note that the transformation of the measured indicators into the analyzed ones can lead to additional errors [1]. Therefore, it is desirable to ensure that the analyzed indicators are directly measurable.

Figure 1. Structural diagram of the ecosystem management system
4. Practical part

For the operation of this system, we need all of the following:
1. To list the indicators that determine the state of the control object.
2. To specify the methods for identifying the values of the state indicators. These techniques can be determined in hardware measurements or with the help of expert assessments. Hardware evaluations are considered more objective and therefore preferable.
3. To state the desired values of the indicators of the management object. If the state of the control object is described by indicators with desired values, then this state is considered desirable. The purpose of the control is to bring the control object to the desired state. The process of changing the state indicators during the transition from the current state to the desired state is called a transient process. Restrictions may be imposed on it. If the control object has reached the desired state, but the transient process has not satisfied the constraints, the control objective is not considered to be achieved.
4. To identify the control factors (impacts). The subject of management uses them when acting on the control object in order to change the state of the latter.
5. To conduct theoretical and experimental studies. "Transient function" of the control object is established. To specify changes in the value of the control object state indicators under certain control actions. This problem can be considered as building a model (mathematical, physical, computational, etc.) of the control object.
6. It is necessary to determine the initial control algorithms. They can be later changed and optimized as a result of investigating the management system.

As a result of joint implementation of positive and negative feedbacks (internal or caused by human activity) in measuring the state of the ecosystem, various forms of transient processes are formed (Figure 2). The system is either stable or unstable according to A. M. Lyapunov [2].

Figure 2. Different forms of transient processes.

Computer methods of control are complex systems. They are developed in modern industry. They are gradually beginning to be applied to the management of territories as a part of implementing rational nature management. This is part of the system analysis. It is devoted to some reasonable
behavior in uncertain conditions, in particular, in order to establish the criteria for optimality and the development of management techniques for these criteria. Ecosystem can be represented by a complex multiply connected graph. A graph is a model with probabilistic characteristics (Figure 3) [3,4].

Figure 3. A graph as a model.

We have an example of the development and implementation of the management systems in the history of modern civilization. These systems are close to ecosystems in complexity. They represent industrial enterprises, or industries. They were initially developed in late 19th - early 20th century in the US automotive industry. They were connected with the introduction of conveyor production methods. In mid-20th century, the mathematical foundations of optimal control were developed: operational research, economic method, linear programming, game theory, etc. At the end of the 20th century computers with high performance and reasonable price appeared. Many software products have been developed. They supported the existing management concepts (MRP, ERP, network planning, quality management, etc.). The description of this management principle for the local ecosystem is presented at Figure 4.

Figure 4. Local ecosystem management system.
5. Conclusion

In conclusion, we would like to state that we have made an analogy between management in environmental and industrial fields, i.e. we considered an ecosystem in environmental management as an analogy to an enterprise in industrial management. We have established the structural components of the simulation model applicable to natural objects. With its help, it is possible to apply system analysis to the theory of ecosystem management.

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