Lecture 2. Descriptions, basic structures and stages of systems analysis

The purpose of the lecture: introduction of the basic conceptual apparatus of system analysis, systems theory. The basic concepts of system analysis, system features, types of system topology, various forms of systems description, stages of system analysis are considered.

Lecture plan:
Introduction
1 System and its parts
2 System structure
3 System description
Conclusion

Keywords: system definition, object, mathematics, informatics, knowledge, system state, attitude, output, goal, task, presentation, resource allocation, fair, description, system, identification, poorly formalized, whole, structure, divisions, works, SI, LLC, pipeline computing, treelike, subtree, hypercube, computer, poorly structured, system description, internal description, external description, operations, morphological, functional description, informational, informational description, morphological description, mouse, information centers, intrasystem information, search, corporate network, terminal, file server, mail server, router, network printer, workstation, server, heterogeneous system, homogeneous system, communication, definition, route, system attribute, connectivity, integrity, value, integral system, system model, functional, poorly formalized system.

Contents of the lecture:

Introduction

Systems analysis, whose foundations are quite ancient, is still a relatively young science (comparable in age, for example, to cybernetics). Although it is actively developing, its defining concepts and terms are not sufficiently formalized (if it is possible at all). Systems analysis is applied in any subject area, including both private and general research methods and procedures.

1 System and its parts

Let us first give an intuitive definition of a system and a subsystem.

System - an object or process in which the participating elements are connected by some connections and relationships.

A subsystem is a part of a system with some connections and relationships.

Any system consists of subsystems; a subsystem of any system can itself be considered as a system. The boundaries of the system under consideration are determined by the available resources and environment.

Example. Science is a system that ensures the receipt, verification, fixation (storage), and actualization of society's knowledge. Science has subsystems:

mathematics, computer science, physics, economics, etc. Any knowledge exists only in the form of systems (systematized knowledge). Theory is the most developed system of their organization, which allows not only describing, but also explaining, predicting events and processes.

Let us define the basic concepts of system analysis, which are required below.

The state of the system is the fixation of the totality of resources available to the system (material, energy, information, spatial, temporal, human, organizational) that determine its attitude to the expected result or its image. This is a "photograph" of the mechanism for transforming the input from the system into output.

The goal is an image of a non-existent, but desirable, from the point of view of the task or the problem under consideration, the state of the environment, i.e. such a state that allows you to solve the problem with the given resources. This is a description, a representation of some of the most preferable (in terms of the goal and available resources) state of the system.

Example. The main socio-economic goals of society: economic growth; full employment of the population; economic efficiency of production; stable price level; economic freedom of producers and consumers; equitable distribution of resources and benefits; socio-economic security and security; trade balance in the market; fair tax policy.

A task is a set of initial premises (input data to the task), a description of a goal defined over a set of these data, and, perhaps, a description of possible strategies for achieving this goal or possible intermediate states of the object under study.

To solve a task means to clearly define the resources and ways to achieve the specified goal with the initial assumptions. Problem solution - description, presentation of the state of the system, at which the specified goal is achieved; the process of finding this state is also called the solution of the problem.

The concept of a problem in systems analysis is broader than the concept of a task, and usually consists of a number of interrelated tasks.

A problem is a description, at least meaningful, of a situation in which the following are defined: the goal, the attainable (achievable, desirable) results and, possibly, the resources and strategy for achieving the goal (solution). The problem is manifested by the behavior of the system.

Description (specification) of a system is the identification of its defining elements and subsystems, their interrelationships, goals, functions and resources, i.e. description of admissible states of the system.

If the input premises, the goal, the problem statement, the solution, or, perhaps, even the very concept of the solution is poorly (partially) described, formalized, then these problems are called ***poorly formalized***. Therefore, when solving such problems, one has to consider a whole complex of formalized problems with the help of which this poorly formalized problem can be investigated. The complexity of their research lies in the need to take into account the various and often contradictory criteria for determining, evaluating the solution to the problem.

Example. Poorly formalized will be, for example, the tasks of restoring "blurry" texts, images, drawing up a curriculum in any large university, drawing up a "formula for measuring intelligence", describing the functioning of the brain, society, translating texts from one language to another using a computer, etc.

2 System structure

Let us define, not yet formalized, the concept of the structure of the system.

A structure is everything that brings order to a set of objects, i.e. a set of connections and relationships between parts of the whole, necessary to achieve the goal.

Example. Examples of structures: gyrus of the brain, faculty, government, crystal lattice of matter, microcircuit. The crystal lattice of a diamond is a structure of inanimate nature; honeycomb and zebra stripes - structures of wildlife; lake - the structure of ecological nature; party (public, political) - the structure of social nature, etc.

Basic topologies of structures (systems) are shown in Fig. 2.1-2.4.

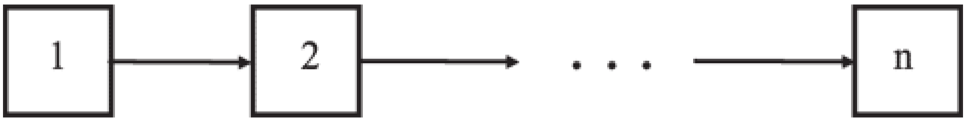

Figure 2.1. Linear type structure

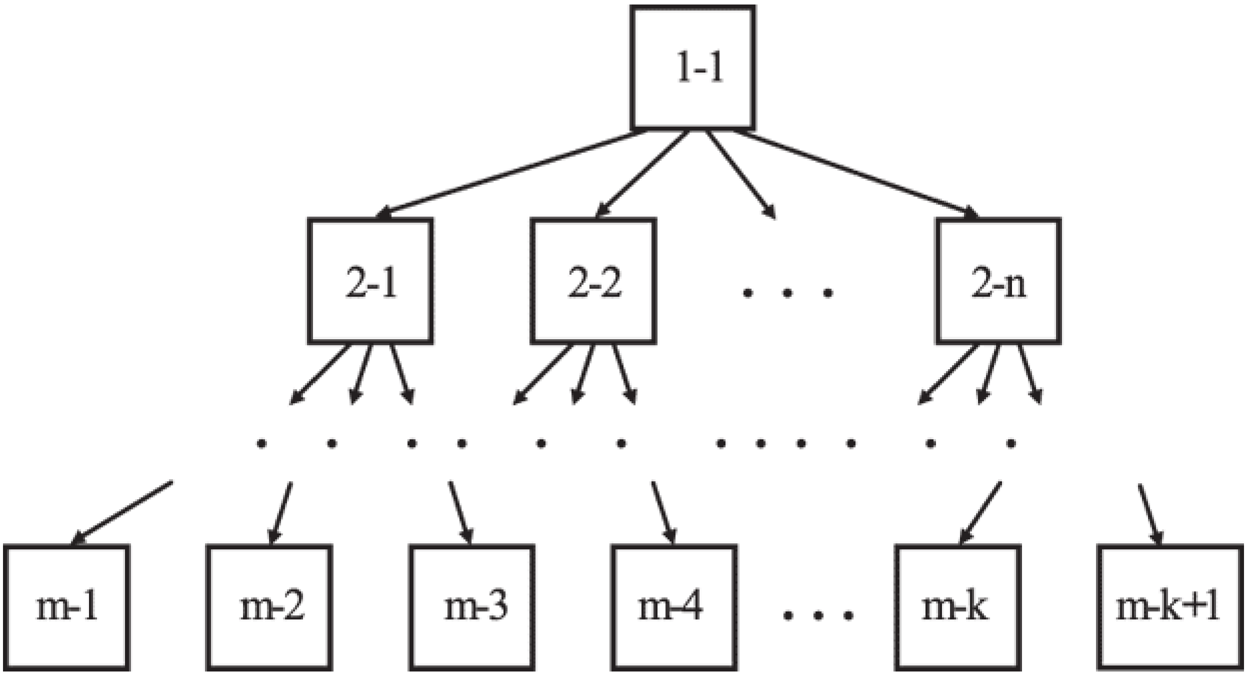

Figure 2.2. Hierarchical structure (first digit - level number)

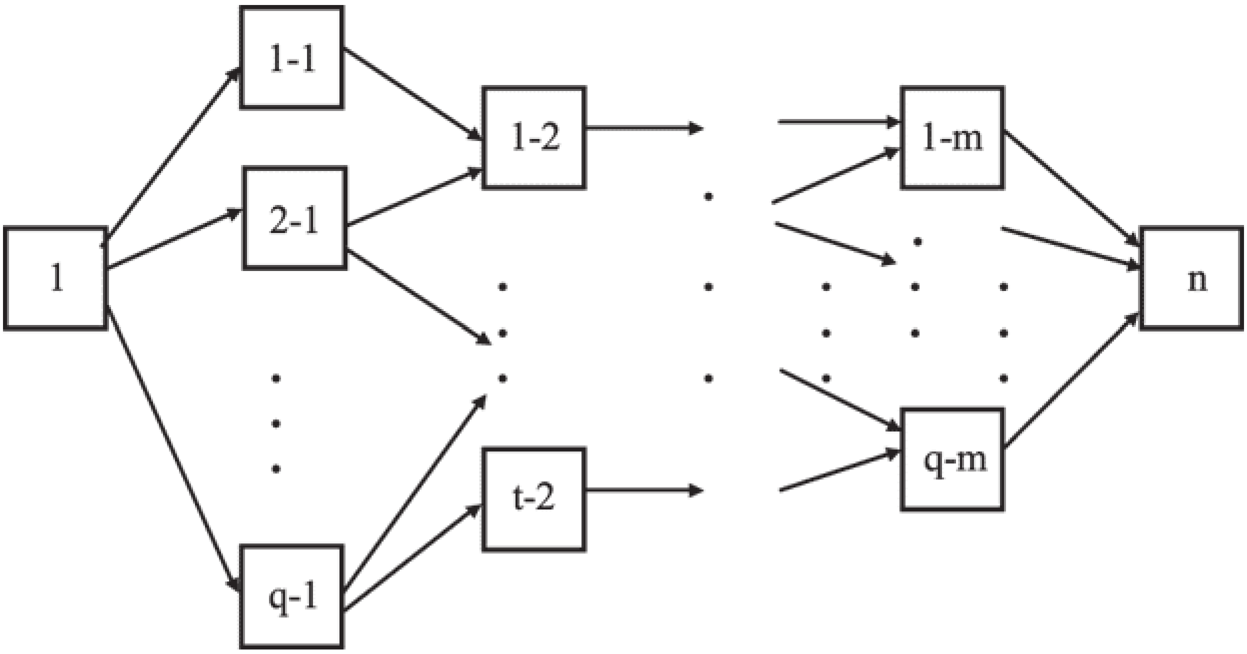

Figure 2.3. Network type structure (the second digit is the number in the path)

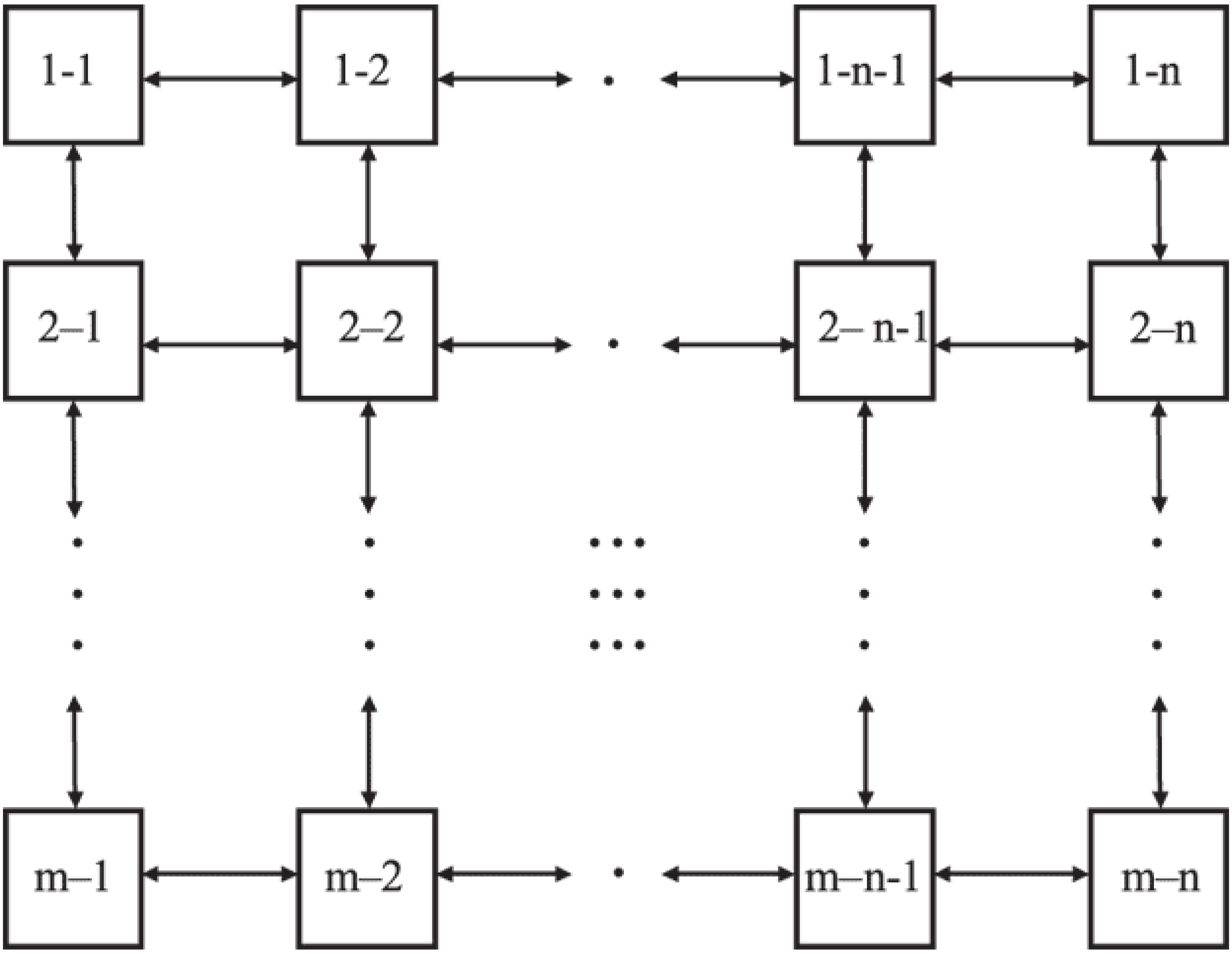

Figure 2.4. Matrix type structure

Example. An example of a linear structure is the structure of metro stations on one (not circular) line in one direction. An example of a hierarchical structure is the management structure of a university: "Rector - Vice-rector - Dean - Head of the department, department - Lecturer of the department, employee of the department". An example of a network structure is the structure of the organization of work during the construction of a house: some work, for example, installing walls, landscaping, etc., can be performed in parallel. An example of a matrix structure is the structure of employees of a research institute department performing work on the same topic.

In addition to the indicated basic types of structures, others are also used that are formed with the help of their correct combinations - connections and attachments.

Example. From combinations of "planar temporal" matrix structures, a matrix "spatial (time-age)" structure can be obtained. A combination of network structures can again give a network structure. The combination of hierarchical and linear structures can lead to both hierarchical ("hanging" a tree structure on a tree structure) and undefined ("hanging" a tree structure on a linear one). Public systems, corporations in the market with a distribution network, and others can have a mixed structure.

Structures of different types can be obtained from identical elements.

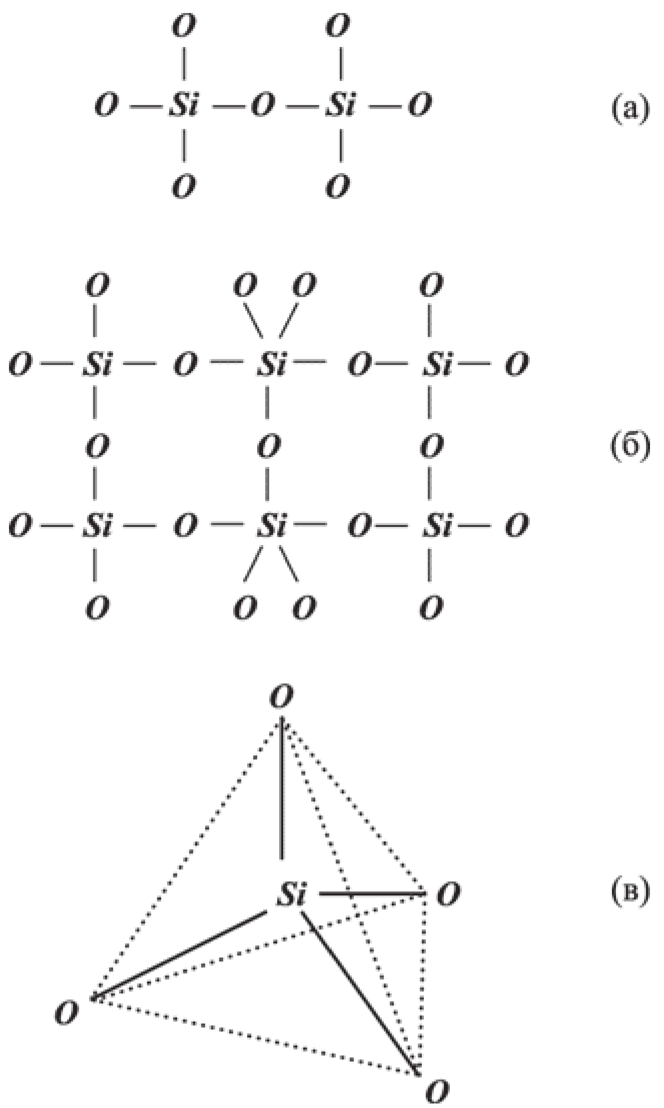

Figure 2.5. Structures of silicon and oxygen macromolecules (a, b, c)

Example. Macromolecules of various silicates are obtained from the same elements (Si, O). This is an example of connections between matter and structure (see Fig. 2.5).

Example. Market structures of various types can be formed from the same market components (resources, goods, consumers, sellers): OJSC, LLC, CJSC, etc. In this case, the structure of the association can determine the properties and characteristics of the system.

In modern computer architectures, computer systems and networks, it is important to choose an efficient structure and topology correctly.

Example. A sequential structure is used when organizing pipelined computing on supercomputers (pipelined computing structures). The network structure (in particular, of the "butterfly" type) is used to organize computations of specialized structures, in particular, for the fast Fourier transform, which is used for processing satellite information and in many other industries. Tree networks are affected by variable latencies where data from all nodes in one subtree must be transferred to another subtree. Two-dimensional arrays (matrices) are often used for image processing. Matrix-matrix structure - a hypercube is used to connect each of the 2n nodes with each, which is different in one binary bit, and organize their independent work on the implementation of individual parts of a large program (task); in particular, a computer of this architecture effectively played chess with G. Kasparov.

The structure is ***connected*** if the exchange of resources between any two subsystems of the system is possible (it is assumed that if there is an exchange of the i-th subsystem with the j-th subsystem, that is, the exchange of the j-th subsystem with the i-th).

If the structure or elements of a system are poorly (partially) described or defined, then such a set of objects is called ***poorly*** or ***weakly structured***.

This is the majority of socio-economic systems that have a number of specific features of poorly structured systems, namely:

1. the multi-aspect nature and interconnectedness of the processes occurring in them (economic, social, etc.), the impossibility of their structuring, since all the phenomena occurring in them must be considered in aggregate;
2. lack of sufficient information (usually quantitative) about the dynamics of processes and the applicability of only qualitative analysis;
3. variability and multivariance of the dynamics of processes, etc.

Example. The problems of describing many historical eras, problems of the microworld, social and economic phenomena, for example, the dynamics of the exchange rate in the market, crowd behavior, etc., will be poorly structured.

Poorly formalized and poorly structured problems (systems) most often arise at the intersection of various sciences, in the study of synergistic processes and systems.

"System" translated from Greek means "whole, made up of parts." This is one of the abstractions of systems analysis, which can be concretized, expressed in concrete forms.

We can now give the following, more complete definition of the system.

A system is a means to an end or everything that is necessary to achieve a goal (elements, relationships, structure, work, resources) in a given set of objects (operating environment).

To describe a system, it is important to know what it has structure (structure), functions (work) and connections (resources) with the environment.

The set of elements and connections between them makes it possible to judge the structure of the system.

3 System description

Any system has internal states, an internal mechanism for converting input data into output (internal description), and also has external manifestations (external description).

The internal description gives information about the behavior of the system, about the correspondence (inconsistency) of the internal structure of the system with the goals, subsystems (elements) and resources in the system, ***the external description*** - about the relationship with other systems, with the goals and resources of other systems (see Fig. 2.6).

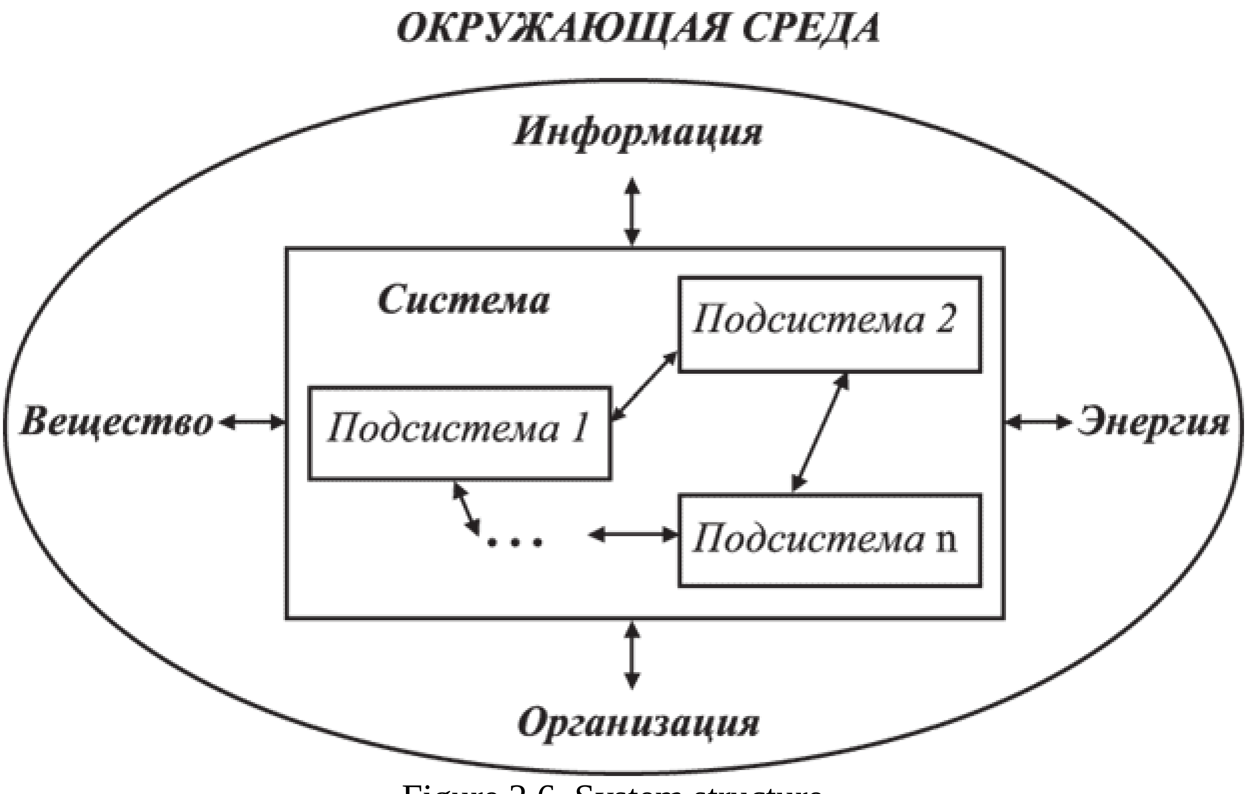

Figure 2.6. System structure

The external description of the system is determined by its internal description.

Example. The bank is a system. The external environment of the bank is a system of investments, financing, labor resources, standards, etc. Input actions are characteristics (parameters) of this system. Internal states of the system - characteristics of the financial state. Output impacts - flows of loans, services, investments, etc. The functions of the system are banking operations, for example, lending. The functions of the system also depend on the nature of the interactions between the system and the external environment. Many functions performed by the bank (system) depend on external and internal functions that can be described (represented) by some numerical and / or non-numerical, for example, qualitative, characteristics or characteristics of a mixed, qualitative and quantitative nature.

A morphological (structural or topological) ***description*** of a system is a description of the structure or structure of a system or a description of the set A of the elements of this system and the set of relations R between these elements of the system necessary to achieve the goal.

A functional description of a system is a description of the laws of functioning, evolution of the system, algorithms of its behavior, "work".

Informational (informational-logical or infological) ***description*** of a system is a description of informational connections of both the system with the environment and subsystems of the system.

Previously, the informational description of the system was called cybernetic.

Example. The morphological description of an ecosystem may include the structure of predators and prey living in it, their trophic structure (food structure), their properties, and connections. The trophic structure of the "predators and prey" type is formed by two disjoint sets X and Y with the properties S(X) and S(Y). Let us take the Russian language with algebraic elements as the language of morphological description. Then we can offer the following simplified model morphological description of this system:

S = <A, B, R, V, Q>

A = {man, tiger, kite, pike, ram, gazelle, wheat, wild boar, clover, field mouse (vole), snake, acorn, crucian carp},

X = {man, tiger, kite, pike, boar, snake, ram},

Y = {gazelle, wheat, clover, vole, acorn, crucian carp},

S(X) = {reptile, two-legged, four-legged, floating, flying},

S(Y) = {living creature, grain, grass, nut},

B = {land dweller, water dweller, vegetation},

R = {predator, prey}.

The trophic structure ("x eats y") of such an ecosystem can be described by the following table 2.1:

Table 2.1. Trophic structure of the ecosystem

Y\X	Human	Tiger	Kite	Pike	Snake	Boar	Ram
Gazelle	1	1	0	0	0	0	0
Wheat	1	0	0	0	0	1	0
Clover	0	0	0	0	0	0	1
Vole	0	0	1	0	1	0	0
Acorn	0	0	0	0	0	1	0
Crucian carp	1	0	0	1	0	0	0

An informational description of the system using a graph is shown in Fig. 2.7

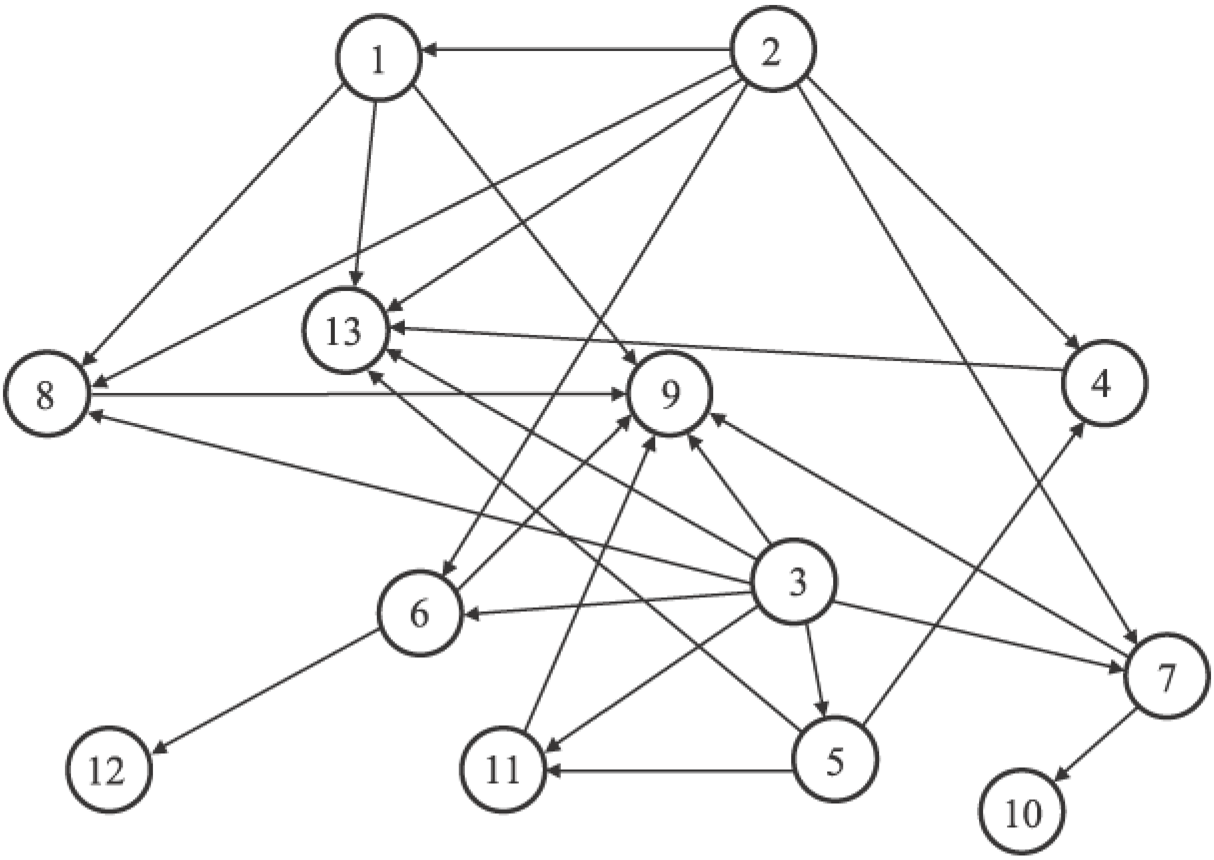

Figure 2.7. Graph of informational description: 1 - human, 2 - tiger, 3 - kite, 4 - pike, 5 - snake, 6 - wild boar, 7 - ram, 8 - gazelle, 9 - wheat, 10 - clover, 11 - vole, 12 - acorn, 13 - crucian carp

If we use the results of population dynamics, then using the given morphological description of the system, we can write down an adequate functional description of the system. In particular, the dynamics of relationships in this system can be written in the form of the Lotka-Volterra equations:

$$x_i'(t) = x_i(t)\left(a_i - \sum_{j-1}^{7} b_{ij} x_j(t)\right), \quad x_i(0) = x_{i0}, \quad i = 1,2,\dots,6;$$

where $x_i(t)$ is the size (density) of the i-th population, b_{ij} is the coefficient of eating the i-th prey species by the j-th species of predators (gluttony), a_i is the fertility rate of the i-th species.

Example. Consider the Information Center system. Input, output and intra-system information is represented by documents, graphic, audio and video files, programs, etc. System functions: provision of computer time, data processing, information retrieval, creation and processing of archives and databases. Systemic goals: the introduction of new information technologies, the introduction of new methods of training personnel and users, increasing the efficiency of searching, receiving, processing and storing information. Description of the system: $x(t + 1) = x(t) - a(t)\,x(t) + b(t)\,x(t)$, where $x(t)$ is the efficiency of methods of working with information at time t; a(t) - coefficient of computer illiteracy of users; b(t) - coefficient showing the degree of implementation of new hardware and software.

Example. "Corporate Network" system, S = <A, B, R, V, Q>, A = {Terminal, File Server, Mail Server, Hub, Router, Network Printer}, B = {Workstation, Server Station, Transmission Devices packets from one subnet to another}, R = {Client, Server}.

In terms of morphological description, the system can be:

- ✓ *a **heterogeneous system** - containing elements of different types, origins (subsystems that are not detailed into elements from the point of view of the chosen approach of morphological description);*
- ✓ ***homogeneous system** - i.e. contain elements of only one type, origin;*
- ✓ *a mixed system - with heterogeneous and homogeneous subsystems.*

The morphological description of the system depends on the connections taken into account, their depth (connections between the main subsystems, between secondary subsystems, between elements), structure (linear, hierarchical, network, matrix, mixed), type (feedforward, feedback), character (positive, negative).

Example. A morphological description of an automaton for the production of a certain product may include a geometric definition of the product, a program (setting a sequence of actions for processing a workpiece), a statement of the operating situation (processing route, restrictions on actions, etc.). The description depends on the type, depth of connections, product structure, etc.

The main features of the system:

- *integrity, connectivity or relative independence from the environment and systems (the most essential quantitative characteristic of the system). With the disappearance of connectivity, the system also disappears, although the elements of the system and even some relations between them can be preserved;*
- *the presence of subsystems and connections between them or the presence of a system structure (the most essential qualitative characteristic of the system). With the disappearance of subsystems or connections between them, the system itself can also disappear;*
- *the possibility of isolation or abstraction from the environment, i.e. relative isolation from those environmental factors that do not sufficiently affect the achievement of the goal;*
- *links with the environment for the exchange of resources;*
- *subordination of the entire organization of the system to some goal (as, however, follows from the definition of the system);*
- *emergence or irreducibility of system properties to the properties of elements.*

The whole is always a system, and integrity is always inherent in the system, manifesting itself in the system in the form of symmetry, repetition (cyclicity), adaptability and self-regulation, the presence and preservation of invariants.

"In an organized system, each part or side complements the others and in this sense is needed for them as an organ of the whole that has a special significance" (Bogdanov A.A.).

When systematic analysis of objects, processes, phenomena, it is necessary to go through (in the specified order) the following stages of system analysis:

1. *Problem (task) detection.*
2. *Assessment of the urgency of the problem.*
3. *Formulation of goals, their priorities and research problems.*
4. *Definition and refinement of research resources.*
5. *Allocation of the system (from the environment) using resources.*
6. *Description of subsystems (opening their structure), their integrity (connections), elements (opening the structure of the system), analysis of the interconnections of subsystems.*
7. *Construction (description, formalization) of the structure of the system.*
8. *Establishment (description, formalization) of the functions of the system and its subsystems.*
9. *Aligning the goals of the system with the goals of the subsystems.*
10. *Analysis (testing) of system integrity.*
11. *Analysis and assessment of the emergence of the system.*
12. *Testing, verification of the system (system model), its functioning.*
13. *Analysis of feedback from system tests.*
14. *Clarification, correction of the results of the previous paragraphs.*

Conclusion

"In an organized system, each part or side complements the others and in this sense is needed for them as an organ of the whole that has a special meaning" (Bogdanov A.A.).

Control questions

See the manual on the organization of students' independent work.