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ALGORITHM FOR CREATING STRUCTURED DIAGRAMS OF AUTOMATIC CONTROL SYSTEMS

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Abstract: As a unique approach to the research of automatic control systems, the algorithm for creating structural schemes, which is one of the forms of their mathematical models, is described. An example of the use of this algorithm is the structure of the automatic control system of the greenhouse temperature. In this work, the object of research is the automatic control system, and the subject of research is the structural scheme of this system. It is shown that if the automatic control system is divided into parts, i.e. elements, their mathematical description becomes easier. As a result of the work, an algorithm for creating structural schemes of automatic control systems is presented. In order to create a structural scheme of the automatic control system, it is necessary to differentiate and separate the elements of this system from each other in different ways; signs of the functional blocks of the management system were distinguished.

Keywords: automatic, control, system, structure, control elements, scheme, model, control object, control device, adjuster, algorithm, feedback.

Introduction. It is known that the social significance of current production is increasingly growing [1], accordingly, research is being conducted on the study of automatic control systems [2, 3, 4], and the results of these studies are being included in textbooks and teaching manuals [5, 6]. In the study of automatic control systems, it has been accepted to present them in the form of mathematical expressions, for example, differential equations - mathematical models, as a unified approach [7, 8, 9, 10, 11, 12]. If an automatic control system (ACS) is divided into parts, i.e., elements, it becomes easier to describe them mathematically, and constructing mathematical models for such parts is simpler than constructing a mathematical model for the system as a whole (Figure 1). To obtain a mathematical model of an ACS, it is necessary to distinguish and separate the elements of this system using various methods, for example, dividing the system into separate special blocks according to structural features, differentiating the functions of various parts of the system, and also presenting it with algorithms. In this work, in connection with such a way of viewing ACSs, the following types of diagrams are distinguished and their definitions are given: structural diagram, functional diagram, and algorithmic diagram. Such diagrams, in turn, serve as a basis for composing differential equations of ACSs, from this point of view, creating a method, an algorithm for obtaining structural diagrams of ACSs is considered relevant in the field of science and technology for automating and controlling technological processes and production.

Methods. We consider the ACS as consisting of parts, i.e., elements, and to reflect the set of these system elements and their interconnections, we introduce the concept of structure. By structure, we mean a set of properties associated with the size, shape, and composition of an object. When we depict the structure, a structural diagram appears. Thus, a structural diagram is a representation of the set of system elements and their interconnections; the concept of structure differs from the concept of the system itself in that when describing the structure, only the types of elements and connections are taken into account, without specifying the values of their parameters.

Structural diagram - is a graphical representation of the system divided into blocks in the sense of mathematical description, which reflects the directions of transmitting influences from the external environment to the system, as well as between the blocks.

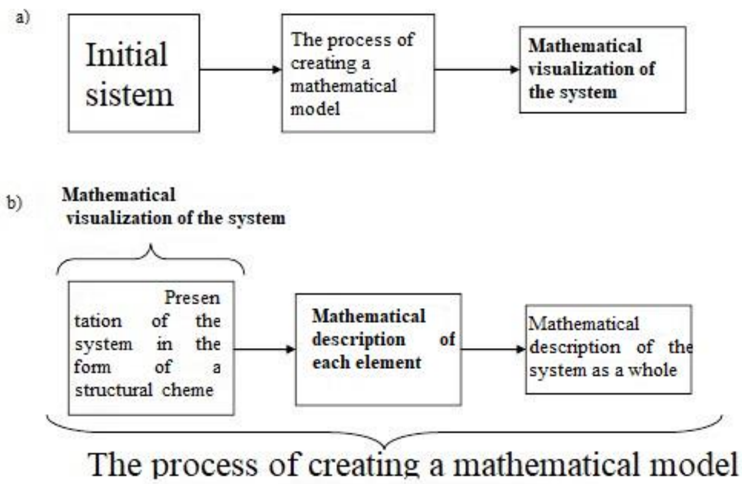

Figure 1. The initial stage of mathematical description of an automatic control system

From this definition, it follows that there can be two types of structural diagrams: a) a structural diagram illustrating the main functional parts of the system, their purpose, and the connections between them, which we will call a ***functional structural diagram***; b) a diagram mathematically describing the interactions of variables within the system and the system's interaction with the external environment, which we will call a ***transfer function structural diagram***.

In the first case (Figure 2), the name of the functional part is written inside each rectangle representing a functional part of the system.

In the second case (Figure 3), the expression of the transfer function known from literature is placed inside the rectangle. If the expression of the transfer function is not available in the literature, it is determined based on differential equations describing the dynamic relationship between the input and output variables of the functional part.

The structural diagram can be constructed with a greater or lesser degree of detail depending on the level of research and the problem of studying the automatic control system.

Diagrams showing only the main or aggregated parts of the control system are called generalized diagrams.

It is also possible to complicate the diagram by showing the elements of the system in more detail, but only if necessary for the study, because the simpler the initial description, the easier the remaining work becomes.

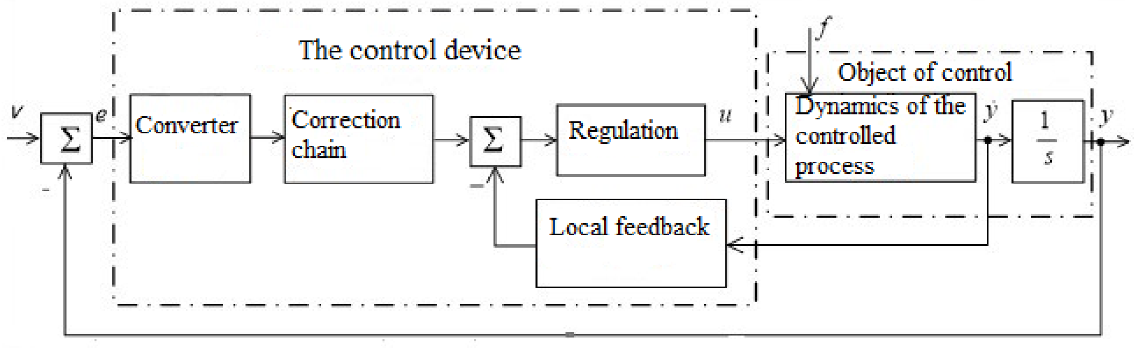

Figure 2. Functional structural diagram of the system

For example, in a car, one can distinguish only what controls it (the driver) and the car itself, or one can take into account the many devices that are part of the car: the braking system, internal combustion engine, transmission, etc., all of which can be shown.

We emphasize that it is necessary to start with a simple, basic diagram, and then attempt to detail it.

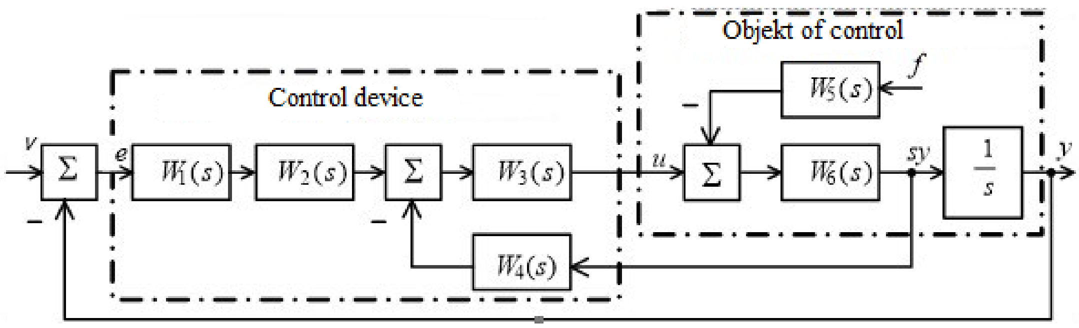

Figure 3. Transfer function structural diagram of the system

The 'simplest' diagram of an ACS is considered to be a diagram showing the control object and the control device connected (Figure 4).

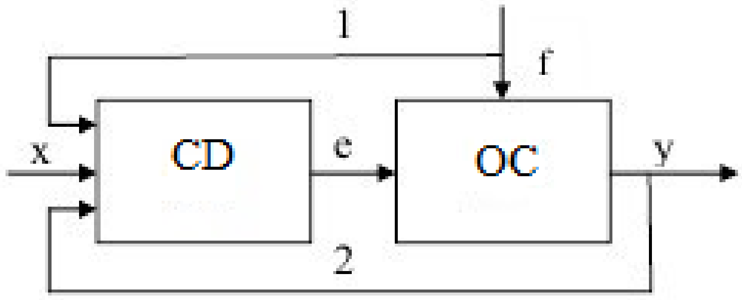

Figure 4. Generalized functional structural diagram of the control system

A **control object** is a device that implements a dynamic process to realize the objectives set for a technical system whose activity can and should be controlled.

A **control device** (CD) is a device that exerts influence on the control object in accordance with the control algorithm. The control device also has other names: **regulator**, if it ensures the maintenance of the controlled variable at a constant level or within a constant range, and **control subject**, as a rule, if a person, group of people, or organization is set as the control device.

Figure 4 also shows the system's signals: x - setting (input) effect; e - control effect; y - controlled (regulated, adjusted) variable (output effect); f - disturbing effect. Chains 1 and 2 may or may not be present depending on the system in question. If we somehow receive information about the results of the control process, then chain 1 is involved, for example, the driver directly sees which direction and at what speed the car is moving, in a temperature regulation system for a room or building, a temperature sensor is involved to know how to control the temperature: increase or decrease. Chain 2 is implemented if the system has ideas about effects that interfere with advance control, i.e., disturbances present in this system. For example, weather compensators are introduced into the system, where for a heating system, the set temperature is changed in advance by an outdoor temperature sensor (compensation is carried out according to weather conditions): the colder it is, the higher the temperature of the heat carrier is set, and vice versa.

A **functional structural diagram** is a diagram reflecting the functions (purpose, intended use) of individual parts of the control system and their interactions.

Such functions may include:

- control;
- signal conversion;
- signal comparison, etc.

The names of devices in the functional diagram indicate that they perform a certain function:

- sensor (measuring converter);
- amplifier;
- comparison block (or summator);
- control device;

- executive element, etc."

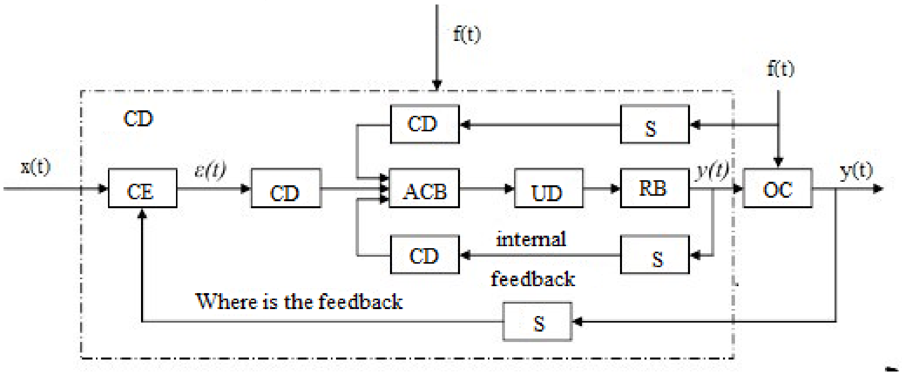

Figure 5. Functional diagram of the ACS

Figure 5 depicts the following functional devices:

S - Sensor - generates a signal proportional to a specified effect;

CE - Comparison Element - designed to compare the controlled variable x(t) (in our case) with the setting effect x_s.e(t) (in our case), by generating a signal proportional to the deviation of these variables from each other;

CC - Corrective Circuit - designed to change the structure of the system in order to improve control quality indicators;

AAB - Amplifying-Adapting Block - serves to amplify the signal and convert it into the required form;

RO - Regulating Organ - serves for direct influence on the regulated environment (examples of RO: valve, gate valve, thyristor, etc.);

ED - Executive Device - designed to actuate the regulating organ (examples of ED: electric motor, electromagnet, drive).

In this diagram (Figure 5), the control device and the control object are separated by a dotted line.

The algorithm for obtaining a functional diagram (Figure 5) is as follows:

1. Determine the controlled variable by clearly specifying the purpose of the system, this is done by answering the question: what is this system for and what are the results of its work?

2. Isolate the control object based on the controlled variable, this should answer the question: what do we control in the system, what implements the control variable, or in which object is the controlled variable present or located. The control object itself can be considered as a complex system of elements. For example, an airplane, car, steam boiler, computer.

3. We isolate the control device by answering this question: who or what receives the setting effect (and, possibly, the disturbing and controlling effects), who or what exerts its influence on other elements affecting the control object.

4. The control effect (a signal of any nature) comes out of the control device and answers this question: by what means does the control device directly affect the control object or the controlled variable?

Finally, the disturbing effect is determined by answering this question: in addition to the control effect, what other factors affect the controlled variable that interfere with the control purpose (maintaining the output effect at a given level)?

Results. We apply the above algorithm to construct structural and functional diagrams of the automatic control system for greenhouse ventilation.

Let's consider the greenhouse ventilation system. If it gets too hot in the greenhouse, the greenhouse controller receives a corresponding signal from the temperature sensor, turns on the electric motor, which opens the window installed for greenhouse ventilation. Similarly, when the temperature drops, the window closes in the same way. By identifying the points mentioned, we construct a structural diagram:

1. The system is designed to maintain a constant, unchanged air temperature in the greenhouse, so the controlled variable is temperature.
2. The controlled parameter (variable) is located in the greenhouse, hence, the control object is the greenhouse. This observation can also be concluded from the expression of what the system is intended for: "maintaining a constant temperature of the air in the greenhouse (building)".
3. The controller receives the setting effect, it also connects the motor that affects the window position, and monitors the temperature sensor. The controller itself is not controlled by anyone, however, in relatively complex systems, this could be a controller, and there could be a higher-level operator. This serves as the main difference that separates the control device from the actuating mechanism and the regulating organ. Implementing effects to maintain a constant temperature level, the controller in this case is called a regulator.
4. The control effect is the airflow passing through the open window or its absence, as it directly affects the controlled variable - the temperature in the greenhouse.
5. Another factor affecting the controlled variable, in a negative sense relative to the control purpose, can be the air temperature outside the greenhouse. Other disturbances here could be people in the greenhouse or other heating (cooling) objects, but the temperature of the external environment has a stronger effect than others.

The functional structural diagram may include elements such as an actuating mechanism, sensor, regulating organ, comparison element. The only function of the Amplifying-Adapting Block (AAB) is to enlarge the input signal and convert it to another form (for example, from analog to digital); we'll leave out corrective mechanisms for now, as they are only introduced when the system works unsatisfactorily.

The listed elements can be combined into a single control device or control object, for example, the regulating organ - all depends on the structure of the system and control characteristics. It's necessary to have an idea about any control system, so they will be present in the generalized scheme. We distinguish the following characteristics of the functional blocks of the control system:

1. The regulating organ is determined by this question - "what directly implements the control effect on the object?" or what exactly "allows" the implementation of an effect similar to the control effect?

2. The actuating mechanism (or device) can be identified if this question is asked: "how does the control device affect the regulating device?".

3. Sensor - this device was defined above, in essence, this device is considered a "measurer" of quantities in the system. Therefore, to identify the sensor, it is sufficient to answer this question: "what measures the controlled or any quantity in the system?". Sensors can also be called converters, as they convert the regulated signal into a form of electrical voltage convenient for input to the control device.

4. The comparison element is not difficult to identify by its name. This device should calculate the difference between signals or compare them in some other way, for example, compare by exceeding the allowed level.

We'll highlight these elements in the example of the automatic control system for greenhouse ventilation considered above.

1. Here, the outside air directly "affects" the object (greenhouse), the thing that "allows" this effect is the "window", so this window is considered the regulating organ.

2. The electric motor affects the window, it opens or closes the window, so it is considered the actuating mechanism.

3. The controlled variable is measured by the temperature sensor in the greenhouse.

4. The set temperature signal and the actual temperature levels in the greenhouse are compared by voltage between conductors, so the voltmeter measuring this difference is called the comparison element in this case. The appearance of the functional diagram is shown in Figure 4.

5.

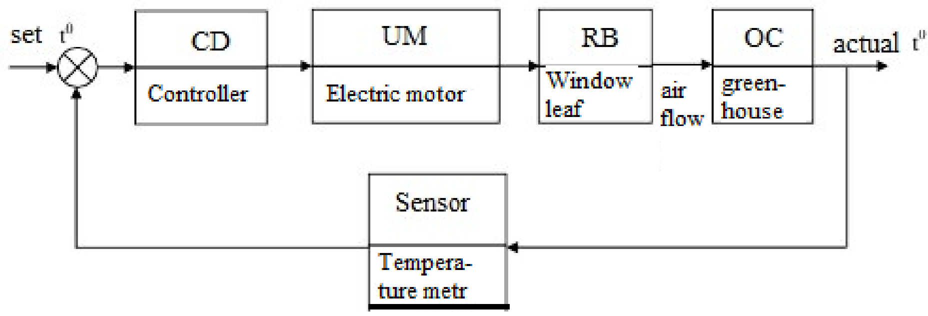

Figure 6. Functional diagram of the greenhouse ACS

Discussions. For a deeper study of objects' activities, schematic, kinematic, and other diagrams can also be used. However, structural or functional diagrams are used most often because they are simpler, more illustrative, can abstract unnecessary factors, and clearly demonstrate the control process throughout the system, as well as allow for an easy understanding of what the system itself is intended for and how it operates.

Conclusion. It has been shown that when an automatic control system is divided into parts, i.e., elements, their mathematical description becomes easier. An algorithm for constructing structural diagrams of automatic control systems has been developed. To construct a structural diagram of an automatic control system, it is necessary to distinguish and separate the elements of this system using various methods; the characteristics of the functional blocks of the control system were highlighted separately.

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