The motion of the system can be considered a goal of the transformations of its states. It is possible to assume that the transition of a system from state a_1 at time t_1 to state a_2 at time t_2 results from a transition of a_1, t_1 to a_2, t_2. The change of output quantities of any system under the influence of changes of input actions can also be considered as their transition.

1.6 Modeling

The existence of similar characteristics for various objects has been used as a basis for the scientific approach to the study of the nature of the most varied phenomena. Essentially, in all sciences, in explicit or implicit form, the concept of a model has been introduced, reflecting similar characteristics of the studied phenomena and objects. But nowhere is the conception of modeling carried through as precisely and sequentially as in the systems approach, where it appears in the most general form and is the fundamental concept determining the methodology used to study the behavior of a system.

Modeling as a method of scientific investigation arose from the necessity to solve problems that for some reason could not be solved directly. Direct investigation of systems is made difficult or impossible when the nature of the system is not easily understood, when the system does not yet exist and the best alternative for its creation needs to be chosen, when the investigation of the system requires much time or effort or is economically unfeasible, and so forth.

For a long time people have used modeling as a means to knowledge. When encountering some unknown, humans first tried to compare this unknown with something they already knew. Comparing an unknown with a known elicits a transfer of knowledge from the second to the first; in other words, the known emerges as a model of the unknown.

The concept of a model is based on the presence of some similarity between two objects. The similarity can be external to the system, or it can belong to the internal structure of objects that are completely dissimilar externally, or it can belong to specific properties of the behavior of objects that do not have anything in common either in form or in structure. The concept of similarity applies to a very wide class of objects, including objects of living and nonliving nature, artificial objects created by people, drawings, symbols, and so on.

If a similarity can be established between two objects, at least in one specific sense, then the relation between these objects can be defined for both the objects and their models. This means that one of these objects can be considered the original and the second considered its model. Consequently, *it is characteristic that all scientific models are representatives of an object of investigation with the model's similarity to the object defined in such a way as to allow one to obtain new knowledge about this object.* As for the specifics of this representative, the character and completeness of the similarity or the correspondence of the model and the original, goals, designations, capabilities of the model, and so forth, can be different.

We will use $\sim$ to denote the similarity of the original and the model such that if an object A is a model of object B, then this relationship can be written in the form $A \sim B$. In this connection, depending on the goals of the investigations, we will also have $B \sim A$, since similarity of objects is always mutual; that is, $\sim$ is a commutative operation. Original-model relations can take place not only between two objects, but also between any number of objects. Thus, for example, for a collection of objects A, B, C, D, where any two objects are similar, B can be considered either a model of objects A, C, and D or the original for models A, C, and D.

External similarity is a similarity of form—for example, objects such as a ship and its illustration (in the form of a three-dimensional model or a set of blueprints of the ship) or a bronze casting and its plaster model. Similarity of structure can be found in a system of instruction and its structural diagram, a city water system, or a city electric power system.

For investigation of a system, the most important similarity between systems resulting in original-model relations is a similarity in their behavior, permitting one to model their motion. At the basis of behavior modeling lies the fact that identical behavior can be observed—for specific conditions—for systems that differ in form, in structure, and in the physical nature of the processes taking place within them.

In the systems approach for posing and solving modeling problems, the concept of a *black box* turned out to be fruitful. *A black box is a system in which only input and output quantities are known to the investigator but the internal structure is unknown.* In this connection, several important conclusions about the behavior of a system can be made by observing only the reaction (behavior) of output quantities after a change in the input quantities. This approach in particular allows one to study systems whose structures either are unknown or are too complicated for analyzing their behavior from the properties of their constituent parts and the connections between these properties.

Let the behavior of a system be determined by its input actions $Y_1, Y_2, \ldots, Y_m$ and output actions $X_1, X_2, \ldots, X_n$ (see Figure 1.5). By observing the behav-

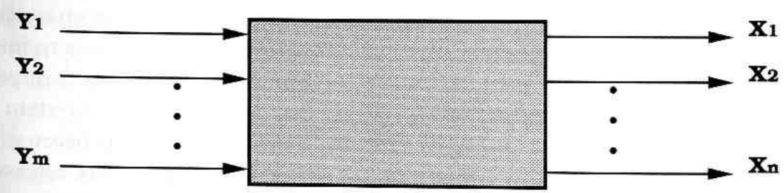

Figure 1.5
Black box.