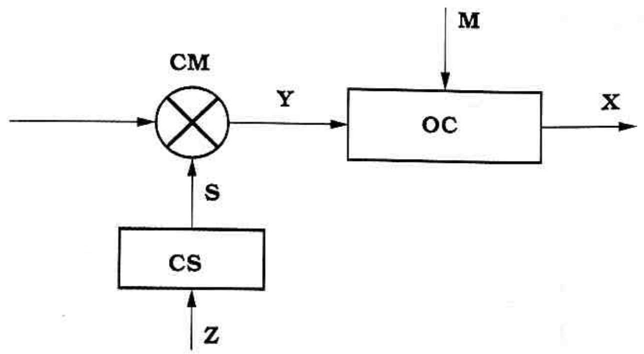

Figure 1.7
The interaction of a control structure with the object of control.

Within the framework of the systems approach, various (in general, similar) definitions of the concept "control" exist. We will use the following: *Control is the action on a system chosen from a set of possible actions, directing the operation or development of a given system*. Figure 1.7 depicts a generalized diagram of a control system.

The object of control and its associated control structure form a *control system*. In order for control signals (S) developed by the control structure (CS) on the basis of information processing (Z) to change the controlling actions (Y), mechanisms are necessary that change the controlling actions in correspondence with the control signals—*control mechanisms* (CM). Input (M) in the diagram represents disturbances influencing the essential output quantities of the system (X). Note that even a human being can play the role of control mechanism, for example, a helmsman turning the rudder of a ship in correspondence with received commands. In this case the helmsman is an element of the control system.

In control systems, four basic types of control problems are considered: program control, stabilization, monitoring, and adaptation.

The problem of *program control* arises when assigned values of control quantities X_0 change in time in a previously known manner. For example, during the control of a ballistic rocket its result at a given trajectory must emerge from a previously known program $X_0(t)$ that measures the change of its position in space and its speed. To control the position of a telescope so as to compensate for the rotation of the earth, the telescope also must be moved by a specific program.

Problems of *stabilization* arise from problems associated with maintaining some of the system's output quantities—*controlled quantities* X near some given constant values X_0, in spite of the action of disturbances M affecting the value X. Thus, to sustain the normal lifetime of a warm-blooded animal, such quantities as body temperature, blood composition, and blood pressure must be stabilized, in spite of changes in the external environment. In power supply systems, voltage and frequency of the current in a network must be stabilized independently of changes in energy use.

When a change in given values of controlled quantities is previously unknown, the problem of *monitoring* arises, that is, how to maintain more precisely the correspondence between the current state of the system $X(t)$ and the value $X_0(t)$. The necessity for monitoring arises, for example, in control of the production of goods during conditions of unforeseen changes in demand; as another example, a radar antenna must turn in order to follow the unforeseen motions of a maneuvering airplane.

A more complicated control problem is *adaptation*. It arises when the control problem cannot be defined as a problem of providing correspondence between the state of a system and its assigned state (fixed or changing), because information about the given state could not have been introduced into the control system earlier nor obtained in the process of its operation. *The process of a change of the properties of a system that permit it to achieve the best or at least optimal operation in changing conditions is called adaptation.*

The property of adaptation distinctly appears in the mechanism of homeostasis, in that a living organism has the ability to maintain its essential coordinates within admissible (physiological) limits during significant changes to conditions in which the organism lives. Adaptability of the mechanism of homeostasis is illustrated by the reaction of warm-blooded animals to a change in the temperature of the environment. During relatively low environmental temperatures, the thermal regulation in the organism is carried out at the expense of a change in blood flow to the surface layer, providing optimal conditions for the organism to exchange heat with the environment. For sufficiently high environmental temperatures, the mechanisms of diaphoresis and respiration provide an intensive release of heat excesses during the process of thermal regulation. Thus, the organism adapts to changing conditions by adapting and changing its behavior and by striving to provide homeostasis (in the given example, the organism strives to maintain body temperature within admissible limits).

Technically or economically controlled systems may be made more adaptable to changing conditions through the use of various modes of choice in the regime of operation or the algorithm for forming the controlling actions, in correspondence with the changing conditions of the system's operation. These changing conditions can consist of changes to the external environment or of changes to properties and characteristics of separate parts of the controlled system. The choice of the most favorable or admissible state of the system is often carried out by means of a *search*.

When choice of the "most favorable" or "best" is required during adaptation, the problem of *optimization* arises. It is well known that the concept "optimal" always means "the best of the available, of the possible." In other words, where no choice exists, the concept of optimality is not used. It is clear that