only those which, under the conditions of the problem under consideration, essentially influence the state of the system. These external actions will be called *input quantities* (or input actions), and elements of the system to which the input actions are applied will be called the *inputs* of the system.

On the motion of an airplane, for example, an essential influence is exerted by such factors as force and direction of the wind, density of the atmosphere, position of the rudders, and pulling forces of the engines. All these factors are considered input actions on an airplane.

It is often useful to consider as the *output quantities of the system* not the coordinates X determining its state, but some other quantities Z uniquely determined by the coordinates of this system. In this connection, each of output quantities Z_i is associated with coordinates of the system by its functional dependence:

$$Z_i = \phi_i(X) \qquad \text{(if there are } k \text{ outputs, then } i = 1, 2, \ldots, k\text{).}$$

The system in this case can be represented in the form of the part of S that transforms input actions Y to coordinates X and the set of functional transformations ϕ that transform coordinates of the system to the output quantities. Figure 1.3 illustrates the transformation of input quantities to output quantities.

The necessity of considering output quantities that are different from the collection of coordinates determining the state of the system arises when the problem consists not of changing the system into a given state, but of achieving a goal functionally associated with the state of a system. Note that this goal is achieved by consciously influencing the system's state, that is, by *controlling* the system. The problem of controlling the process of manufacturing a synthetic fiber, for example, stems from obtaining a fiber of the required strength Z_1 and resilience Z_2. These quantities are associated with the functional dependence with these coordinates of the process: temperature of the material (X_1), content of the admixture (X_2, X_3, . . .) in basic raw materials, and so on. It is clear that in similar cases one must distinguish output quantities from coordinates characterizing the state of the system.

To solve control problems, it is important to distinguish two types of input quantities: control actions and perturbing actions. Control actions include those quantities whose values can be managed to control a system and that can be

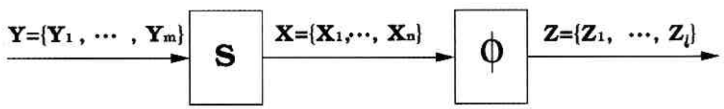

Figure 1.3
Diagram of transformation of input quantities to output, where Y represents input quantities, X represents system coordinates, Z represents output quantities, S represents transformer of input quantities to system coordinates, and ϕ represents transformer of coordinates to output quantities.

changed to realize the motion preferred in comparison with other possible motions of the system. In the given example of an airplane, control actions are created by the steering surfaces and pulling forces of engines, which are dealt with according to the pilot's judgment.

Perturbing actions, the remaining essential actions on the system, are, for example, the effects of the wind and atmospheric density on the motion of the airplane.

The action of a system on the surrounding environment is characterized by the values of its output quantities. The collection of output quantities and their changes determine the behavior of the system; in fact, they permit an external observer to evaluate the correspondence of the system's motion with the goals of control. In the airplane example, output quantities are the course and velocity of its motion, because values of these quantities are determined by the direction and speed of translation of its mass. The goal of control in this case consists of delivering the load to a given place at a given time. Input actions on the organism of an animal are, in particular, actions perceived by its sense organs, and output quantities are motions of its organs.

A change of input quantities, as a rule, causes a change of output quantities. However, changes of output quantities do not always follow immediately; they can sometimes lag but they can never anticipate changes of input quantities, for the former are consequences of the latter, the reason for the system's motion.

Note that perturbing actions affecting the motion of the system not only can have an external source, but can arise within the system as well, such as from changes to properties of its elements after lengthy operation or as a result of a breakdown of the normal operation of the system's elements.

Sometimes it is convenient to consider a system separated into its subsystems, interacting with each other. In this case, some output quantities of one subsystem can simultaneously be input quantities for another subsystem, as shown in Figure 1.4.

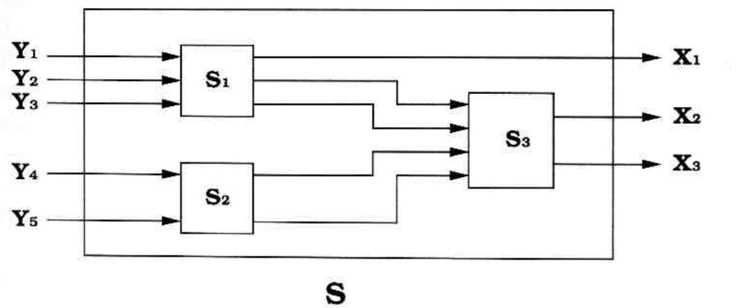

Figure 1.4
Example of the interaction of subsystems within a system.