of living nature, and for them it is impossible to point to a subject having definite goals that can be achieved only if control is carried out. However, even for biological systems, the concept "better behavior" has meaning, which is that the character of an organism's behavior in the environment surrounding it has an essential influence on its survival and reproduction. Therefore, evaluation of the organism's behavior as a controlled system is determined by its interrelations with its environment; "better" behavior, therefore, is that which increases the chance of the given organism to survive and produce offspring.

We mentioned earlier that some external actions on a system, specifically those that can manage its control, are called controlling actions. An action on a system's behavior can be brought about through an action on its coordinates, as well as through a change in the parameters (transition to another state) of the controlled system—*the object of control*. Thus, for example, one can gain control of the rotational speed of a turbine by changing the water pressure h, which is an action on the coordinate representing the rotational moment of the turbine. If the pressure is unknown, the same effect is achieved by changing the incline angle α of the blades on which the water is falling. A change in the angle α results in a change in parameters that determine the characteristics of the turbine—its internal properties. The possibilities of control are greater, and control can be carried out more effectively, the wider the range of values that the controlling actions can take in the control process. However, in real systems the range for which each controlling action can change is limited. In the given example of controlling a turbine, both pressure h and angle α can change only within the specific limits

$$h' \leq h \leq h'', \qquad \alpha' \leq \alpha \leq \alpha''.$$

Because control of any object can be carried out with the help of certain controlling actions, each of which is bounded by some limiting values, in *the space of controlling actions* $Y_1, Y_2, \ldots, Y_m$, we can distinguish a region Q satisfying the conditions

$$Y_i' \leq Y_i \leq Y_i'' \ (i = 1, 2, \ldots, m),$$

within which lies points that represent all possible collections of controlling actions (see Figure 1.6). This region usually is called the *region of possible actions*. Often controlling actions can take only a finite number of fixed values (or may be limited to a finite number). Then the region of possible controlling actions will contain a finite number of possible collections of controlling actions, which are called *the set of possible actions*.

The temperature of a refrigerator, for example, can be maintained near an assigned value by means of injecting and ejecting a refrigerant substance. The set of possible actions of this system consists of two controlling actions: "on" and "off."

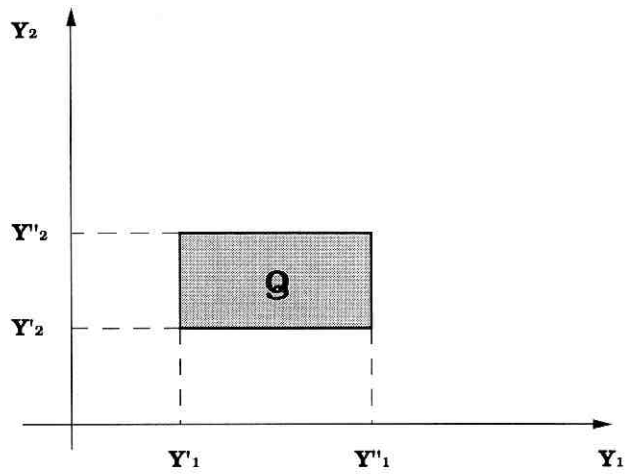

Figure 1.6
Region of possible controlling actions.

In order to control a system, it is necessary to change controlling actions on this system by a specific method. Such a change to the controlling actions can be carried out with the help of *control signals* that maintain communication about the required values of the controlling actions. The collection of elements of the system that operate the control signals is called the *control structure*. If the desired behavior, the conditions for system operation, and its properties are known beforehand, then information about the sequence of controlling actions can be introduced into the controlling structure early on, in the form of *a control program*. Such a control is called a *programmed control*. In other cases, when all data necessary for the creation of a programmed control are unknown beforehand, forming of the controlling actions can be organized into a controlling structure on the basis of information about the conditions arising in the process of system operation. Data about the state of the controlled system, about its desired state, about possible actions, and about characteristics of the controlled system can serve as this information. Processing this information in the control structure by means of specific rules forms a basis for the controlling actions. The collection of rules, by which information appearing in the control structure is processed in the control signal, is called a *control algorithm*.

Note that control is usually needed not only for normal system operation, but also to guarantee that it is developing in the desired direction: for development of an organism from an embryo, for development of a business venture, for development of an economy, and so forth. Control of development arises from the formation of a plan to develop the system and from the realization of this plan.