On CONTROL and Control Systems

Mustafa Kizilcay

The keyword CONTROL evokes in the first moment associations to the following two main subjects

1.) Control of people by higher authorities or by some privileged groups
2.) Control of physical systems, equipment or devices in engineering and in daily life.

The first association has rather a negative meaning. The second one is widely spread and can be found almost in each household appliance. As scientist and engineer I would start to talk on the control of technical systems. They are often called "automatic control systems". Control theory belongs to the fundamental courses at universities in engineering, particularly in electrical and mechanical engineering. Why is the control of various systems so important in our lives?

In my chair of electrical power systems at the Dept. of Electrical Engineering and Computer Science at the University of Siegen we deal with the control of the electrical power systems. We call it also power grid because it is a meshed and complex system. That broad system must work with least disturbance and interruption of power supply 24 hours a day. This is only possible by several control mechanisms installed. We talk about speed and frequency control, voltage control at the power stations. There is power flow and current control, if there is an overlaid high-voltage direct-current transmission system, what we call briefly HVDC system.

There are several course books on control theory and systems. I refer here to only two books in this area [1], [2]. Both are in English. One book [1] by the author Benjamin Kuo printed in 1975 was the course book at that time when I studied electrical engineering at the Middle East Technical University in Ankara. Although those books are relatively old - written 45 years ago! - basic theory has remained almost unchanged in the last four, five decades. Of course, there is a steady progress in the control theory and its applications with regard to the complexity of the representation and methods of analysis of those systems.

I will quote from those two books in order to give an idea of the control of various phenomena at home and at the industry. Even such problems as inventory control, environmental control, social and economic systems control, may be approached from the theory of automatic control. Also, the performance of a philharmonic orchestra on stage can be interpreted as a controlled process, I believe.

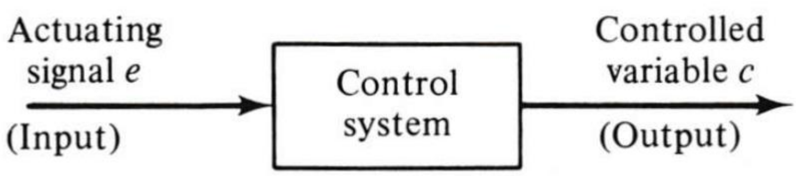

Figure 1: Basic control system [1]

The basic control system concept may be described by the simple block diagram shown in Figure 1. The objective of the system is to control the variable *c* in a prescribed manner by the actuating signal *e* through the elements of the control system. In more common terms, the controlled variable *c* is the output of the system, and the actuating signal is the input.

As a simple example, in the steering control of an automobile, the direction of the two front wheels may be regarded as the controlled variable c, the output. The position of the steering wheel is the input, the actuating signal e. The controlled process or system in this case is composed of the steering mechanism, including the dynamics of the entire automobile. However, if the objective is to control the speed of the automobile, then the amount of pressure exerted on the accelerator is the actuating signal, with the speed regarded as the controlled variable.

A central-heating system or air-conditioning system if operated in conjunction with a room thermostat is said to be automatically controlled, whilst if it is operating without the thermostat it is said to be manually controlled. These systems are shown diagrammatically in Figures 2a and 2b, respectively. In the case of figure 2b, if a change should occur in the outside air temperature, a change in room temperature would result and manual intervention would be needed to correct the room temperature. For the automatically controlled system of figure 2a the effect of a change in outside air temperature on the room temperature would be corrected without manual intervention.

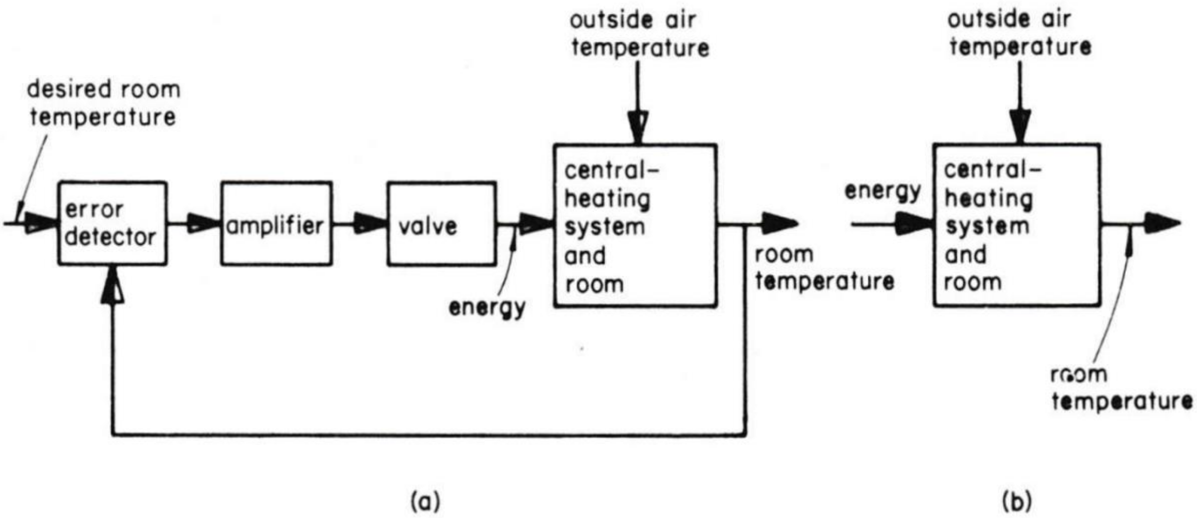

Figure 2: A central-heating system at home [2]

(a) automatic system, called "closed-loop system",
(b) manual system, called "open-loop system"

The manual system is said to operate in open loop and is known as an open-loop system whilst the automatic system is known as a closed-loop system. In a closed-loop system the actual output (room temperature) is measured and compared with the desired output (desired room temperature) and the difference, after amplification, is used to operate a valve or similar device (to increase or decrease the energy input) such that the difference is made as small as possible.

The word automatic implies that there is a certain amount of sophistication in the control system. By automatic, it generally means that the system is usually capable of adapting to a variety of operating conditions and is able to respond to a class of inputs satisfactorily. However, not any type of control system has the automatic feature. When a system does not have the feedback structure, so called an "open-loop system" is the simplest and most economical type of control system. Unfortunately, open-loop control systems lack accuracy and versatility and can be used in none but the simplest types of applications.

In general, the elements of an open-loop control system are represented by the block diagram of Figure 3. An input signal or command *r* is applied to the controller, whose output acts as the actuating signal *e*; the actuating signal then actuates the controlled process and hopefully will drive the controlled variable *c* to the desired value.

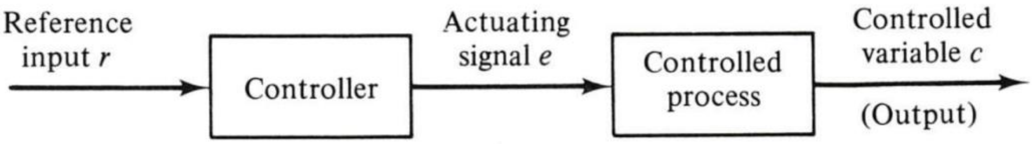

Figure 3: Block diagram of an open-loop control system [1]

What is missing in the open-loop control system for more accurate and more adaptable control is a link or feedback from the output to the input of the system. In order to obtain more accurate control, the controlled signal $c(t)$ - being a function of time - must be fed back and compared with the reference input, and an actuating signal proportional to the difference of the output and the input must be sent through the system to correct the error.

Human beings are probably the most complex and sophisticated feedback control system in existence. A human being may be considered to be a control system with many inputs and outputs, capable of carrying out highly complex operations.

To illustrate the human being as a feedback control system, let us consider that the objective is to reach for an object on a desk. As the hand is reaching for the object, the brain sends out a signal to the arm to perform the task. The eyes serve as a sensing device which feeds back continuously the position of the hand. The distance between the hand and the object is the error, which is eventually brought to zero as the hand reaches the object. This is a typical example of closed-loop control. However, if one is told to reach for the object and then is blindfolded, one can only reach toward the object by estimating its exact position. It is quite possible that the object may be missed by a wide margin. With the eyes blindfolded, the feedback path is broken, and the human is operating as an open-loop system. The example of the reaching of an object by a human being is described by the block diagram shown in Figure 4. The feedback signal has generally a negative sign in the shown closed-loop operation.

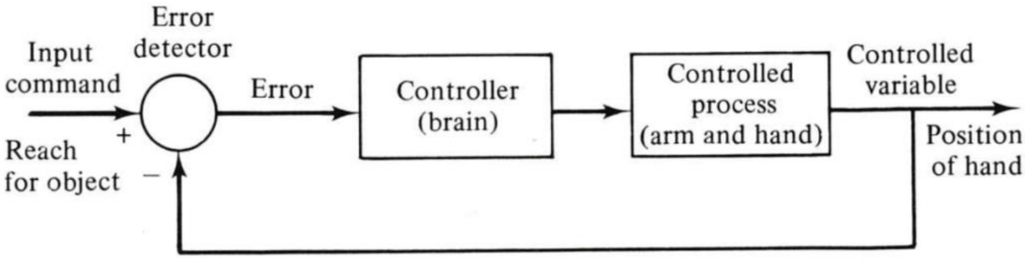

Figure 4: Block diagram of a human being as closed-loop control system [1]

In such basic closed-loop control system there are several factors influencing the system behavior. As it can be easily understood from the above examples, time response is a very important issue. How fast and how smooth should be the operation of performance, so that the desired controlled output is timely achieved?

"Stability" is a notion that describes whether the system will be able to follow the input command. In a non-rigorous manner, a system is said to be unstable, if its output is out of control or increases without bound. The stability is therefore an important factor to be considered in control systems.

The performance of a philharmonic orchestra on stage may be interpreted also as a closed-loop control system. The interaction of the conductor with the orchestra members forms a feedback system. The music score on paper is the reference input, the sound produced by the orchestra members is the controlled variable or output and the interaction of the conductor is the feedback in order to minimize the error in tempo, or?

References

[1] Benjamin C. Kuo: Automatic Control Systems, Third Edition, Prentice-Hall, Inc., New Jersey, 1975.

[2] S. A. Marshall: Introduction to Control Theory, The MacMillan Press Ltd., London, 1978.