Chapter 10

Implementation

10.1 Introduction

So far we have focused on concepts and ideas. Since controllers are actual devices we will now briefly discuss what controllers look like physically. This is difficult for two reasons, control are implemented in many different technologies and the application areas are very wide. Technology has also changed significantly over the years. We will therefore concentrate on the principles and give a few practical illustrations.

Controllers have been described as differential equations or transfer functions. To implement a controller it is necessary to construct a device that solves differential equations in real time. In addition it is necessary to connect the computing device to the process which is done using sensors and actuators. A controller also has other functions apart from the control algorithm itself. Most controllers have facilities for man-machine interaction. Controllers can also operate in different modes. When discussing implementation we must consider issues such as mode, switches, safety, reliability and user interfaces.

Early controllers were implemented with devices that combined sensing, computing and actuation. The centrifugal governor is a typical example. Later as technology developed the different functions were separated. Computing can be done in many different ways using a wide range of technologies. Analog computing was used in the early controllers but today it is typically performed with digital computers. Analog control is still used in devices that require very high speed. It is also commonly used in MEMS devices because analog controllers require less silicon surface than digital controllers.

Feedback has had a central role in the development of sensing, actuation

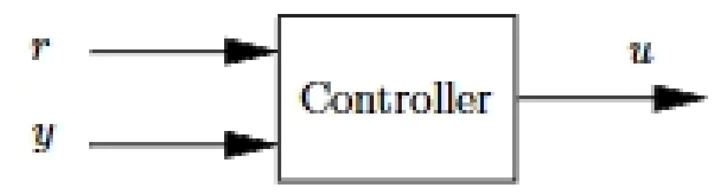

Figure 10.1: An abstract representation of a controller with two degrees of freedom.

and computing. Many advances in the technology have been associated with the introduction of feedback in the devices. There have thus been close synergies between the development of ideas and devices.

A significant standardization has also occured in specific application domains. The advantages of standardization was recognized early in process control where standards for signal transmission were introduced. This made it possible to have different suppliers of sensors, actuators and controllers. It was also possible to collect all controllers into central operating rooms so that operators could have a good overview over large manufacturing processes. Standardization of digital communication is also underway but progress has been slow because of special vendor interest. An interesting feature is that the internet protocol is beeing used increasingly.

Feedback has had an essential role both in analog computing and in implementation of controllers. The devices used to implement controllers are amplifiers and systems with dynamics. The amplifiers can be nonlinear because linear behavior can be created using feedback. The development of controllers is interesting, great ingenuity has often been demonstrated and a wide range of technologies have been used. Today two technologies are predominant. Analog controllers based on operational amplifiers and computer control. Since biological systems use pulse based computing extensively we also include a section on that.

10.2 Sensing Actuation Computing and Communication

For the most part of this book a controller has simply been viewed as a box with two inputs, the reference r, the measured process variable y, and one output, the control variable u as illustrated in Figure 10.1. The linear behavior of a controller is typically described by a transfer function or a differential equation. A more detailed representation of a controller is given in Figure 10.2. In this figure the controller is decomposed into three blocks,

Figure 10.2: A more detailed representation of a controller.

representing sensing, computing and actuation. The sensor converts the physical process variable to a representation that can be handled by the computing device. The computing device performs the operation on the signal expressed by the controller transfer function. The actuator converts the result of the computations to a physical variable that can influence the process. Actuation requires energy or forces.

Many processes have large dimensions and the control system has to cover a large area. For large processes it is therefore common to centralize the computing in a control room or master computer. It is then necessary to connect sensors actuators and computing functions. If signals are represented electrically by currents and voltages the connections are done with wires. If the system have many sensors and actuators there will be a lot of wires and then is is highly advantageous to use communication networks. A wide variety of networks can be used, electrical, optical and wireless. The dimensions of the systems can vary widely. A CD player is about 0.1 m. Systems for a car have sizes of a few meters. Climate control of buildings have sizes of hundreds of meters. For large paper mills the distances can be of the order of kilometers. Power systems cover several nations and the Internet covers practically the whole planet.

Figure 10.3a shows some of the trends in sensing, actuation, and computation in automotive applications. As in many other application areas, the number of sensors, actuators, and microprocessors is increasing dramatically, as new features such as antilock brakes, adaptive cruise control, active restraint systems, and enhanced engine controls are brought to market. The cost/performance curves for these technologies, as illustrated in Figure 10.3b, is also insightful. The costs of electronics technologies, such as sensing, computation, and communications, is decreasing dramatically, enabling more information processing. Perhaps the most important is the role of communications, which is now inexpensive enough to offer many new possibilities.

Modern control engineering is also closely related to the integration of software into physical systems. Virtually all modern control systems are implemented using digital computers. Often they are just a small part of