مفهوم اولیه

سیگنال‌ها و سیستم‌ها

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Abstraction

Input Signal → System → Output Signal

سیگنال: موجودی که دارای اطلاعات است
سیستم: موجودی که کاری را انجام می‌دهد
Example: Mass and Spring

\[ x(t) \]

\[ y(t) \]

Denny Freeman (MIT)
Example: Tanks

\[
\begin{align*}
    r_0(t) & \\
    h_1(t) & \\
    r_1(t) & \\
    h_2(t) & \\
    r_2(t) & \\
\end{align*}
\]
Example: Cell Phone Systems

sound in

sound out

cell phone system

t

t
Example: Modulator

focuses on the flow of information, abstracts away everything else
Example: Endocrine System

Liver
- Insulin-like growth factor (somatomedin)
- Angiotensinogen
- Angiotensin
- Thrombopoietin

Stomach
- Gastrin
- Ghrelin
- Neuropeptide Y
- Somatostatin
- Histamine
- Endothelin

Duodenum
- Secretin
- Cholecystokinin

Pancreas
- Insulin
- Glucagon
- Somatostatin
- Pancreatic polypeptide

Kidney
- Renin
- Erythropoietin
- Calcitriol
- Thrombopoietin

Adrenal glands
- Glucocorticoids
- Mineralocorticoids
- Androgens

Adrenal medulla
- Adrenaline
- Noradrenaline
- Dopamine
- Enkephalin
Example: Endocrine System

Beta cells of the pancreas secrete the hormone insulin into the blood.

Blood glucose level rises (such as after eating).

Blood glucose level falls (such as after fasting).

Beta cells of the pancreas secrete the hormone insulin into the blood.

Insulin enhances the transport of glucose into body cells and stimulates the liver to store glucose as glycogen.

Alpha cells of the pancreas secrete the hormone glucagon into the blood.

Glucagon promotes the breakdown of glycogen in the liver and the release of glucose into the blood.

NORMAL BLOOD GLUCOSE

(70–110 mg glucose/100 mL)
Example: Endocrine System
Example: Transportation System
Systems

1- Data Processing
2- Control (Physical Actions)

1- Fixed
2- Programmable
The neurons of vertebrates and most invertebrates require supporting cells called glial cells, or glia (from a Greek word meaning "glue") (Figure 48.3). Glia nourish neurons, insulate the axons of neurons, and regulate the extracellular fluid surrounding neurons. In addition, glia sometimes function in replenishing certain groups of neurons and in transmitting information (as we'll discuss later in this chapter and in Chapter 49). Overall, glia outnumber neurons in the mammalian brain 10- to 50-fold.
Data Processing vs Control

Campbell Biology

the canal and ventricles fill with cerebrospinal fluid, which is formed in the brain by filtration of arterial blood. The cerebrospinal fluid circulates slowly through the ventricles and central canal and then drains into the veins, supplying the CNS with nutrients and hormones and carrying away wastes.

In addition to these fluid-filled spaces, the brain and spinal cord contain gray matter and white matter (see Figure 49.5).

Gray matter is primarily made up of neuron cell bodies. White matter consists mainly of bundled axons. In the spinal cord, white matter makes up the outer layer, consistent with its function in linking the CNS to sensory and motor neurons of the PNS. In the brain, white matter is predominantly in the interior, where signaling between neurons functions in learning, feeling emotions, processing sensory information, and generating commands.

In vertebrates, the spinal cord runs lengthwise inside the vertebral column, known as the spine (Figure 49.6).

During embryonic development in vertebrates, the central nervous system develops from the hollow dorsal nerve cord—a hallmark of chordates (see Figure 34.3). The cavity of the nerve cord gives rise to the narrow central canal of the spinal cord as well as the ventricles of the brain (Figure 49.5).

Brain

Cranial nerves

Peripheral nervous system (PNS)

Spinal cord

Ganglia outside CNS

Spinal nerves

▲ Figure 49.5 Ventricles, gray matter, and white matter.

Ven - tricles deep in the brain's interior contain cerebrospinal fluid. Most of the gray matter is on the brain surface, surrounding the white matter.

▲ Figure 49.6 The vertebrate nervous system. The central nervous system consists of the brain and spinal cord (yellow). Left-right pairs of cranial nerves, spinal nerves, and ganglia make up most of the peripheral nervous system (dark gold).

▲ Figure 49.4 Newly born neurons in the brain of an adult mouse. In this light micrograph, new neurons derived from adult stem cells are labeled with green fluorescent protein (GFP), and all neurons are labeled with a DNA-binding dye, colored red in this image.
Information processing by a nervous system occurs in three stages: sensory input, integration, and motor output. As an example, let’s consider the cone snail discussed earlier, focusing on the steps involved in identifying and attacking its prey (Figure 48.4). To generate sensory input to the nervous system, the snail surveys its environment with its tubelike siphon, sampling scents that might reveal a nearby fish. During the integration stage, the nervous system processes input to determine if a fish is in fact present and, if so, where the fish is located. Motor output from the processing center then initiates attack, activating neurons that trigger release of the harpoon-like tooth toward the prey.

**Figure 48.3** Glia in the mammalian brain. This micrograph (a fluorescently labeled laser confocal image) shows a region of the rat brain packed with glia and interneurons. The glia are labeled red, the DNA in nuclei is labeled blue, and the dendrites of neurons are labeled green.

**Figure 48.4** Summary of information processing. The cone snail’s siphon acts as a sensor, transferring information to the neuronal circuits in the snail’s head. If prey is detected, these circuits issue motor commands, triggering release of a harpoon-like tooth from the proboscis.

**Figure 48.5** Structural diversity of neurons. In these drawings of neurons, cell bodies and dendrites are black and axons are red. In all but the simplest animals, specialized populations of neurons handle each stage of information processing.

- **Sensory neurons**, like those in the snail’s siphon, transmit information about external stimuli such as light, touch, or smell, or internal conditions such as blood pressure or muscle tension.
- **Neurons in the brain or ganglia** integrate (analyze and interpret) the sensory input, taking into account the immediate context and the animal’s experience. The vast majority of neurons in the brain are **interneurons**, which form the local circuits connecting neurons in the brain.
- **Neurons that extend out of the processing centers** trigger output in the form of muscle or gland activity. For example, **motor neurons** transmit signals to muscle cells, causing them to contract.

In many animals, the neurons that carry out integration are organized in a **central nervous system (CNS)**. The neurons that carry information into and out of the CNS constitute the **peripheral nervous system (PNS)**. When bundled together, the axons of neurons form **nerves**.

Depending on its role in information processing, the shape of a neuron can vary from simple to quite complex (Figure 48.5). Neurons that transmit information to many target cells do so through highly branched axons. Similarly, neurons that have highly branched dendrites can receive input through tens of thousands of synapses in some interneurons.
The Peripheral Nervous System

The PNS transmits information to and from the CNS and plays a large role in regulating both an animal's movement and its internal environment (Figure 49.8). Sensory information reaches the CNS along PNS neurons designated as **afferent** (from the Latin, meaning "to carry toward"). Following information processing within the CNS, instructions then travel to muscles, glands, and endocrine cells along PNS neurons designated as **efferent** (from the Latin, meaning "to carry away"). Most nerves contain both afferent and efferent neurons.

The PNS has two efferent components: the **motor system** and the **autonomic nervous system** (see Figure 49.8). The **motor system** consists of neurons that carry signals to skeletal muscles. Motor control can be voluntary, as when you raise your hand to ask a question, or involuntary, as in the knee-jerk reflex controlled by the spinal cord. In contrast, regulation of smooth and cardiac muscles by the **autonomic nervous system** is generally involuntary. The three divisions of the autonomic nervous system—**sympathetic**, **parasympathetic**, and **enteric**—together control the organs of the digestive, cardiovascular, excretory, and endocrine systems. For example, networks of neurons that form the **enteric division** of the autonomic nervous system are active in the digestive tract, pancreas, and gallbladder.

**Figure 49.8** Functional hierarchy of the vertebrate peripheral nervous system.
Data Processing vs Control
Data Processing vs Control
Function

Both the structure and functioning of a computer are, in essence, simple. Figure 1.1 depicts the basic functions that a computer can perform. In general terms, there are only four:

- Data processing
- Data storage
- Data movement
- Control

The computer, of course, must be able to process data. The data may take a wide variety of forms, and the range of processing requirements is broad. However, we shall see that there are only a few fundamental methods or types of data processing.

It is also essential that a computer store data. Even if the computer is processing data on the fly (i.e., data come in and get processed, and the results go out immediately), the computer must temporarily store at least those pieces of data that are being processed.

Data movement apparatus

Control mechanism

Operating environment (source and destination of data)

Data storage facility

Data processing facility

Figure 1.1 A Functional View of the Computer
Data Processing vs Control
Data Processing vs Control
Data Processing vs Control

Advantages of Control Systems

A control system can produce the needed power amplification, such as a knob at the input, which requires a large amount of power for its output. For example, a radar antenna, positioned by low-power rotation, can be used in various applications.

Control systems, position and velocity in mechanical systems, and voltage, current, and temperature in electrical systems are examples of variables controlled by control systems.

For disturbances, a control system must correct the output even with a disturbance. For example, consider an antenna that is in the wrong position or has noise entering internally. The system must compensate for these disturbances.

Control systems can also provide convenience by changing input form to a desired output. For example, a remote-controlled robot arm can be used to pick up material in a radioactive environment. Figure 1.4 shows a robot arm.

A control system is designed to work in contaminated environments. For example, a robot arm can be used to pick up material in a radioactive environment.

Control systems are also useful in remote or dangerous locations. For example, a remote-controlled robot arm can be used to pick up material in a radioactive environment.

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Discussion of the performance of control systems is important, as the transient response and steady-state error are key performance indicators.

There are two major measures of performance in control systems: (1) the transient response and (2) the steady-state error. In our example, passenger comfort and passenger patience are important performance specifications since passenger safety and convenience would be at risk in the absence of an automated system.

A control system consists of a network of subsystems, including motors, control systems, regulated position and velocity, and controlled variables like temperature. The objective is to achieve the desired performance with the given specifications.

Our eyes follow a moving object to keep it in view; our hands grasp the object and place it precisely at a desired location. This is an example of a control system in action.

Figure 1.1 shows the desired response and input command for the elevator location (floor).

Time

Elevator location (floor)

Input command

Transient response

Steady-state error

Steady-state response

Elevator response

Because of control systems, elevators carry passengers safely and efficiently. Today, elevators are fully automated, using control systems.

In the past, elevators were controlled by an operator. Here a rope is cut to stop an elevator. An operator would also change the direction of the elevator. In innovation in early elevators, a man towered down a long arm to change the direction of the elevator. A counterbalance to the other.

Before the invention of elevators, people had to physically move to the desired floor. In modern elevators, we press a button to call the elevator, and it arrives at the correct floor automatically. This is an example of an automatic control system.

Because of control systems, elevators carry passengers safely and efficiently. Today, elevators are fully automated, using control systems.

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FIGURE 1.1

Desired response

Input command

Elevator location (floor)

Time

Elevator response

Transient response

Steady-state error

Steady-state response

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Data Processing vs Control
Data and instructions are stored in a single read–write memory. The contents of this memory are addressable by location, without regard to the type of data contained there. Execution occurs in a sequential fashion (unless explicitly modified) from one instruction to the next.

The reasoning behind these concepts was discussed in Chapter 2 but is worth summarizing here. There is a small set of basic logic components that can be combined in various ways to store binary data and to perform arithmetic and logical operations on that data. If there is a particular computation to be performed, a configuration of logic components designed specifically for that computation could be constructed. We can think of the process of connecting the various components in the desired configuration as a form of programming. The resulting “program” is in the form of hardware and is termed a hardwired program.

Now consider this alternative. Suppose we construct a general-purpose configuration of arithmetic and logic functions. This set of hardware will perform various functions on data depending on control signals applied to the hardware. In the original case of customized hardware, the system accepts data and produces results (Figure 3.1a). With general-purpose hardware, the system accepts data and control signals and produces results. Thus, instead of rewiring the hardware for each new program, the programmer merely needs to supply a new set of control signals.

How shall control signals be supplied? The answer is simple but subtle. The entire program is actually a sequence of steps. At each step, some arithmetic or logical operation is performed. The sequence of steps is defined by the control signals, which are specified by the programmer.

Figure 3.1
Hardware and Software Approaches
Fixed vs Programmable
Analysis and Design
1.5 The Design Process

In this section, we establish an orderly sequence for the design of feedback control systems that will be followed as we progress through the rest of the book. Figure 1.10 shows the described process as well as the chapters in which the steps are discussed.

The antenna azimuth position control system discussed in the last section is representative of control systems that must be analyzed and designed. Inherent in Figure 1.10 is feedback and communication during each phase. For example, if testing (Step 6) shows that requirements have not been met, the system must be redesigned and retested. Sometimes requirements are conflicting and the design cannot be attained. In these cases, the requirements have to be respecified and the design process repeated. Let us now elaborate on each block of Figure 1.10.

**Step 1: Transform Requirements Into a Physical System**

We begin by transforming the requirements into a physical system. For example, in the antenna azimuth position control system, the requirements would state the desire to position the antenna at a specific location. The next step is to draw a functional block diagram. From this diagram, we transform the physical system into a schematic. We then obtain a block diagram, signal-flow diagram, or state-space representation. If multiple blocks, we reduce the block diagram to a single block or closed-loop system.

**Step 2: Draw a functional block diagram.**

**Step 3: Transform the physical system into a schematic.**

**Step 4: Use the schematic to obtain a block diagram, signal-flow diagram, or state-space representation.**

**Step 5: If multiple blocks, reduce the block diagram to a single block or closed-loop system.**

**Step 6: Analyze, design, and test to see that requirements and specifications are met.**

**Mathematical Modeling**

In summary, then, our design objectives and the system's performance revolve around the transient response, the steady-state error, and stability. Gain adjustments can affect performance and sometimes lead to trade-offs between the performance criteria. Compensators can often be designed to achieve performance specifications without the need for trade-offs. Now that we have stated our objectives and some of the methods available to meet those objectives, we describe the orderly progression that leads us to the final system design.

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**Figure 1.10**

The control system design process.
Case Study: Concept (Input-Output)

FIGURE 1.8

(a) Antenna azimuth position control system:

- **a.** System concept;
- **b.** Detailed layout;
- **c.** Schematic (figure continues)

\[
\theta_i(t) \to \text{Desired azimuth angle input} \to \text{Potentiometer} \to \theta_o(t) \to \text{Azimuth angle output}
\]
Case Study: Detailed Layout

FIGURE 1.8 Antenna azimuth position control:
(a) system concept;
(b) detailed layout;
(c) schematic (figure continues)

\[ \theta_i(t) \]
Desired azimuth angle input

\[ \theta_o(t) \]
Azimuth angle output

Potentiometer

Differential amplifier and power amplifier

Motor

Antenna

(b)
Desired azimuth angle input

Potentiometer

θ_i(t)

Potentiometer

θ_o(t)

Motor

Fixed field

Armature

Armature resistance

Differential and power amplifier

K

Amplifiers

Inertia

Viscous damping

(c)

Gear

(c)

(c)
If we increase the gain of the signal amplifier, will there be an increase in the steady-state value of the output? If the gain is increased, then for a given actuating signal, the motor will be driven harder. However, the motor will still stop when the actuating signal reaches zero, that is, when the output matches the input. The difference in the response, however, will be in the transients. Since the motor is driven harder, it turns faster toward its final position. Also, because of the increased speed, increased momentum could cause the motor to overshoot the final value and be forced by the system to return to the commanded position. Thus, the possibility exists for a transient response that consists of damped oscillations (that is, a sinusoidal response whose amplitude diminishes with time) about the steady-state value if the gain is high. The responses for low gain and high gain are shown in Figure 1.9.

We have discussed the transient response of the position control system. Let us now direct our attention to the steady-state position to see how closely the output matches the input after the transients disappear.

We define steady-state error as the difference between the input and the output after the transients have effectively disappeared. The definition holds equally well for step, ramp, and other types of inputs. Typically, the steady-state error decreases with an increase in gain and increases with a decrease in gain. Figure 1.9 shows zero error in the steady-state response; that is, after the transients have disappeared, the output position matches the input position.
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Interconnection of Systems

Cascade

Input Signal → System I → Output Signal → Input Signal → System II → Output Signal

Parallel

Input Signal → System I → Output Signal → System II → Output Signal

Input Signal → System I → Output Signal

Input Signal → System II → Output Signal
Interconnection of Systems

Feedback

System I

Input Signal

Output Signal

System II

Input Signal

Output Signal