自动控制专业英语

Reading English for Control Engineering

谈振藩 编

哈尔滨工程大学出版社

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内容简介

全书分为十章,前九章是经典控制理论方面的内容,第十章是现代控制理论中状态空间分析法方面的部分内容。本书节选了原版教科书中的部分章节作了注释和编译,通过阅读可以帮助读者尽快掌握本专业的基础词汇,提高阅读和理解专业文献的能力。

本书可作为工业自动化,自动控制,检测技术及仪器,机电一体化,导航、制导与控制专业本科开设"专业英语阅读"课程的教材。

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前　言

自动控制从本世纪初成为一门独立的学科以来，已走过了漫长的道路，并经历了"经典控制理论"和"现代控制理论"两大阶段。目前，自动控制在基本理论和应用技术方面的研究，已成为信息时代科学技术发展的重要组成部分。今天，自动控制科学广泛应用于航空航天、工业过程自动化、机器人技术、电子通讯、计算机控制、智能仪器仪表等高新技术领域。而且，控制论已经成为经济和社会问题研究中的基本思想。为了跟踪控制领域的世界先进水平，了解研究的前沿，作为自动控制专业的本科生和研究生除了牢固掌握本专业的基本理论和应用技术之外，还应能熟练阅读本专业的外文书籍、文献和资料。本着这一宗旨，节选了《Introduction to Control Systems》和《Modern Control Systems》两书中的部分章节作了注释和编译，以帮助学生通过阅读本书尽快掌握控制理论中的基本词汇。在内容的选择上，既注意了基本概念的连续性，词汇的覆盖面和重复性，又避免了过多的推导和过量的例题。全书内容共分 10 章，前 9 章以经典控制理论中的线性部分为主，因为这是整个控制理论的基础。同时也兼顾了非线性和离散控制理论。考虑到大部分院校对控制专业本科生也开设了现代控制理论中有关状态空间分析法的课程，所以第 10 章选择了相关的内容。本书可作为工科院校工业自动化，自动控制，检测技术及仪器，导航、制导与控制，机电一体化等专业本科开设"专业英语阅读"课程的教材，也可作为相关专业工程技术人员自学的教材。

由于编者水平有限，书中错误和不足之处在所难免，敬请读者批评指正。

CONTENTS

1 Introduction

1.1 HISTORICAL PERSPECTIVE

The desire to control the forces of nature has been with man since early civilizations. Although many examples of control systems existed in early times, it was not until the mid-eighteenth century that several steam operated control devices appeared. This was the time of the steam engine, and perhaps the most noteworthy invention was the speed control flyball governor invented by James Watt.

Around the beginning of the twentieth century much of the work in control systems was being done in the power generation and the chemical processing industry. Also by this time, the concept of the autopilot for airplanes was fairly well developed.

The period beginnign about twenty-five years before World War Two saw rapid advances in electronics and especially in circuit theory, aided by the now classical work of Nyquist in the area of stability theory. The requirements of sophisticated weapon systems, submarines, aircraft and the like gave new impetus to the work in control systems before and after the war. The advent of the analog computer coupled with advances in electronics saw the beginning of the establishment of control systems as a science. By the mid-fifties, the progress in digital computers had given the engineers a new tool that greatly enhanced their capability to study large and complex systems. The availability of computers also opened the era of data-logging, computer control, and the state space of modern method of analysis.

The sputnik began the space race and large governmental expenditures in the space as well as military effort. During this time. circuits became miniaturized and large sophisticated systems could be put together very compactly thereby allowing a computational and control advantage coupled with systems of small physical dimensions. We were now capable of designing and flying minicomputers and landing men on the moon. The post sputnik age saw much effort in system optimization and adaptive systems.

Finally, the refinement of the chip and related computer development has created an explosion in computational capability and computer-controlled devices. This has led to many innovative methods in manufacturing methods, such as computer-aided design and manufacturing, and the possibility of unprecedented increases in industrial productivity via the use of computer-controlled machinery, manipulators and robotics.

Today control systems is a science with the art still playing an important role. Much mathematical sophistication has been achieved with considerable interest in optimal control system. The modern approach, having been established as a science, is being applied not only to the traditional control systems, but to newer problems like urban analysis, econometrics, transportation, biomedical problems, energy analysis, and a host of similar problems that affect modern man.

1.2 BASIC CONCEPTS

Control system analysis is concerned with the study of the behavior of dynamic systems. The analysis relies upon the fundamentals of system theory where the governing differential equations assume a cause-effect relationship. A physical system may be represented as

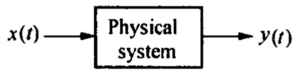

Fig. 1-1 A physical system

shown in Fig. 1-1, where the excitation or input is $x(t)$ and the response or output is $y(t)$. A simple control system is shown in Fig. 1-2. Here the output is compared to the input signal, and the difference of these two signals becomes the excitation to the physical system, and we speak of the control system as having feedback. The *analysis* of a control system, such as described in Fig. 1-2, involves the obtaining of $y(t)$ gvien the input and the characteristics of the system. On the other hand, if the input and output are specified and we wish to design the system characteristics, then this is known as *synthesis*.

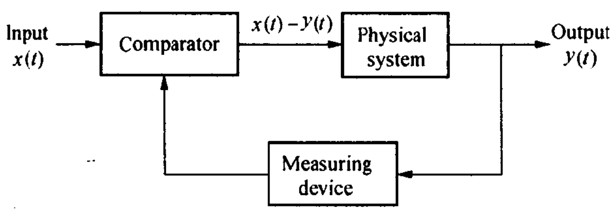

Fig. 1-2 A simple control system

A generalized control system is shown in Fig. 1-3. The *reference* or *input variables* $r_1, r_2, \cdots, r_m$ are applied to the *comparator* or *controller*. The *output variables* are $c_1, c_2, \cdots, c_n$. The signals $e_1, e_2, \cdots, e_p$ are *actuating* or *control variables* and are applied by the controller to the *system* or *plant*. The plant is also subjected to *disturbance inputs* $u_1, u_2, \cdots, u_q$. If the output variable is not measured and fed back to the controller, then the total system consisting of the controller and plant is an *open loop system*. If the output is fed back, then the system is a *closed loop system*.

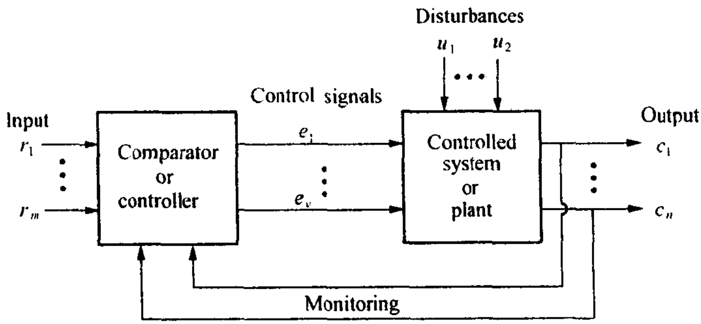

Fig. 1-3 A general control system

1.3 SYSTEMS DESCRIPTION

Because control systems occur so frequently in our lives, their study is quite important. Generally, a control system is composed of several subsystems connected in such a way as to yield the proper cause-effect relationship. Since the various subsystems can be electrical, mechanical, pneumatic, biological, etc., the complete description of the entire system requires the understanding of fundamental relationships in many different disciplines. Fortunately, the similarity in the dynamic behavior of different physical systems makes this task easier and more interesting.

As an example of a control system consider the simplified version of the attitude control of a spacecraft illustrated in Fig. 1-4. We wish the satellite to have some specific attitude relative to an inertial coordinate system. The actual attitude is measured by an attitude

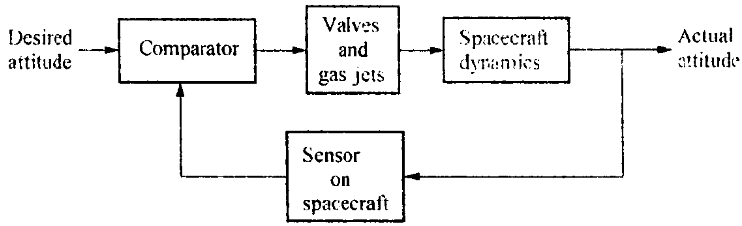

Fig. 1-4 Control of satellite attitude

sensor on board the satellite. If the desired and actual attitudes are not the same, then the comparator sends a signal to the valves which open and cause gas jet firings. These jet firings give the necessary corrective signal to the satellite dynamics thereby bringing it under control. A control system represented this way is said to be represented by block diagrams. Such a representation is helpful in the partitioning of a large system into subsystems and thereby allowing the study of one subsystem at a time.

If we have many inputs and outputs that are monitored and controlled, the block diagram appears as illustrated in Fig. 1-5. Systems where several variables are monitored and controlled are called *multivariable* systems. Examples of multivariable systems are found in chemical processing, guidance and control of vehicles, the national economy, urban housing growth patterns, the postal service, and a host of other social and urban problems.

The number of control systems that surround us is indeed very large. The essential feature of all these systems is in general the same. They all have input, control, output, and disturbance variables. They all describe a controller and a plant. They all have some type of a comparator. Finally, in all cases we want to drive the control system to follow a set of preconceived commands.

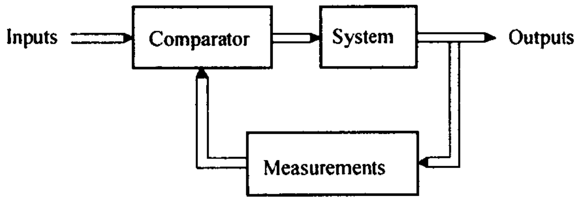

Fig. 1-5 Representation of a multivariable system

1.4 DESIGN, MODELING, AND ANALYSIS

Prior to the building of a piece of hardware, a system must be designed, modeled, and analyzed. Actually the analysis is an important and essential feature of the design process. In general, when we design a control system we do so conceptually. Then we generate a mathematical model which is analyzed. The results of this analysis are compared to the performance specifications that are desired of the proposed system. The accuracy of the results depends upon the quality of the original model of the proposed design. We shall show, in Chapter7, how it is analyzed and then modified so that its performance satisfies the system specifications. The objective then may be considered to be the prediction, prior to construction, of the dynamic behavior that a physical system exhibits, i. e. its natural motion when disturbed from an equilibrium position and its response when excited by external stimuli. Specifically we are concerned with the speed of response or transient response, the accuracy or steady state response, and the stability. By stability we mean that the output remains within certain reasonable limiting values. The relative weight given to any special requirement is dependent upon the specific application. [2] For example, the air conditioning of the interior of a building may be maintained to ±1℃ and satisfy the occupants. However, the temperature control in certain cryogenic systems requires that the temperature be controlled to within a fraction of a degree. The requirements of speed, accuracy, and stability are quite often contradictory and some compromises must be made. For example, increasing the accuracy generally makes for poor transient response. If the damping is decreased, the system oscillations increase and it may take a long time to reach some steady state value.

It is important to remember that all real control systems are nonlinear; however, many can be approximated within a useful though limited range as linear systems. Generally, this is an acceptable first approximation. A very important benefit to be derived by assuming linearity is that the superposition theorem applies. If we obtain the response due to two different inputs, then the response due to the combined input is equal to the sum of the individual responses. Another benefit is that operational mathematics can be used in the analysis of linear systems. The operational method allows us to transform ordinary differential equations into algebraic equations which are much simpler to handle.

Traditionally, control systems were represented by higher-order linear differential equations and the techniques of operational mathematics were employed to study these equations. Such an approach is referred to as the *classical method* and is particularly useful for analyzing systems characterized by a single input and a single output. As systems began to become more complex, it became increasingly necessary to use a digital computer. The work on a computer can be advantageously carried out if the system under consideration is represented by a set of first-order differential equations and the analysis is carried out via matrix theory. This is in essence what is referred to as the *state space* or state variable approach. This method, although applicable to single input-output systems, finds important applications in the multivariable system. Another very attractive benefit is that it enables the control system engineer to study variables inside a system.

Regardless of the approach used in the design and analysis of a control system, we must at least follow the following steps:

(1) Postulate a control system and state the system specifications to be satisfied.

(2) Generate a functional block diagram and obtain a mathematical representation of the system.

(3) Analyze the system using any of the analytical or graphical methods applicable to the problem.

(4) Check the performance (speed, accuracy, stability, or other criterion) to see if the specifications are met.

(5) Finally, optimize the system parameters so that (1) is satisfied.

词　　汇

advent[ˈædvənt]　n.(事件,时期的)出现,到来

analog[ˈænəlɔg]　n.模拟,类似

assume[əˈsjuːm]　vt.假设,表现为,采取(某形式)

autopilot[ˈɔːtəpailət]　n.自动驾驶仪

biomedical[ˈbaiouˈmedikəl]　n.生物医学

closed-loop[ˈklouzdˈluːp]　n.闭环

comparator[ˈkɔmpəreitə]　n.比较器

couple[ˈkʌpl]	vt. 耦合,匹配
cryogenic[ˌkraiəˈdʒenik]	a. 低温的
datalogging[deitəˈlɔgiŋ]	n. 数据采集
dimension[diˈmenʃən]	n. 尺寸,维数,量纲
discipline[ˈdisiplin]	n. 学科
enhance[inˈhaːns]	n. 增强,提高
equilibrium[ˌiːkwiˈlibriəm]	n. 平衡
excitation[ˌiksiˈteiʃən]	n. 激励
expenditure[iksˈpenditʃə]	n. 支出,花费
impetus[ˈimpitəs]	n. 促进,刺激 •
innovative[ˈinouveitiv]	a. 创新的,革新的
manipulator[məˈnipjuleitə]	n. 机械手
miniaturize[ˈminjətʃəraiz]	v. 使小型化
multivariable[ˌmʌltiˈvɛəriəbl]	a. 多变量的
noteworthy[ˈnoutˌwəːði]	n. 显著的,值得的
open-loop[ˈoupenˈluːp]	n. 开环
optimization[ˌɔptimaiˈzeiʃən]	n. 最优化,最佳化
partition[paːˈtiʃən]	n. vt. 划分
performance[pəˈfɔːməns]	n. 性能,特征
perspective[pəˈspektiv]	n. 展望,观点,透视
postulate[ˈpɔstjuleit]	vt. 假定,以…为出发点
plant[plaːnt]	n. (被控)对象,设备
pneumatic[njuːˈmætik]	a. 气动的
response[risˈpɔns]	n. 响应
robotics[rəuˈbɔtiks]	n. 机器人学
sensor[ˈsensə]	n. 传感器
sophisticated[səˈfistikeitid]	n. 高级的,尖端的,老练的
spacecraft[ˈspeiskraːft]	n. 空间飞行器
specitication[ˌspesifiˈkeiʃən]	n. (性能)指标,规格