自动控制原理 Automatic Control Theory

西南交通大学
电气工程学院

2019

Introduction

Course Text and References ：

Primary course text book:

- Modern Control Systems(12th Edition)

  (英文影印版). 电子工业出版社 2015. Richard C. Dorf, Robert H. Bishop.

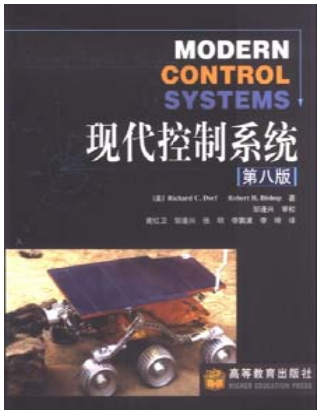
Additional references:

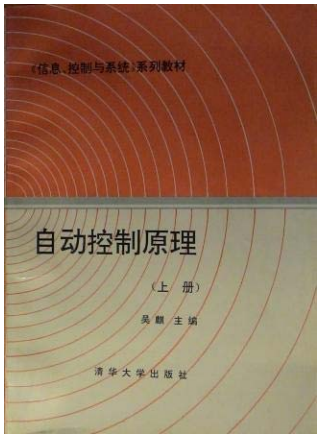
- 现代控制系统(第十二版).电子工业出版社, 2015. Richard C. Dorf, Robert H. Bishop, 谢红卫等译
- 自动控制原理(第二版). 高等教育出版社, 2010, 黄家英
- 自动控制原理. 清华大学出版社, 吴麒

E-mail:zhaoduo@swjtu.edu.cn

Introduction

Course Text and References ：





E-mail:zhaoduo@swjtu.edu.cn

Introduction

Instructor

zhaoduo@swjtu.edu.cn

153 9002 9122

欢迎任何形式的意见和建议！

请添加qq群

备注名：
学号+姓名

群名称:自动控制原理
群　号:446528349

E-mail:zhaoduo@swjtu.edu.cn

Introduction

Grading

The final grade will be based on *homework sets*, *Experiments Reports*, a *midterm exam*, and a *final exam*:

- *Homework (about 10%):* Homework sets will be handed out weekly. and due on next Thursday. Late homework will not be accepted without prior permission from the instructor.
- *Midterm exam (about 20%):* A midterm exam will be handed out at the beginning of midterms week (9-10th week).
- *Experiments (about 10%):* Eight experiments will be carried out during this semester.
- *Final exam (about 60%):* The final exam will be handed out on the Exam week.

E-mail:zhaoduo@swjtu.edu.cn

Introduction

Homework sets

Collaboration Policy

- Collaboration on home
  You may consult outsic
  students or the instruct
  homework solutions frc
- All solutions that are ha
  individually and should
  of the subject matter at
- No collaboration is allo
  exams.

raged.
er
up
ding

西南交通大学电气工程学院

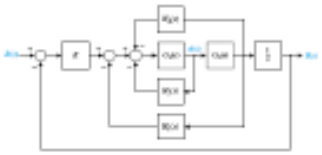
课程名称：自动控制原理　　课程编号：324398

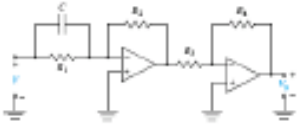
指导教师：赵舵	作业编号：No.2	作业发布时间：2006.03.04
课程时间：2006		作业提交时间：2006.03.14

注意：1、请在作业本封面注明姓名、学号、专业、班级；

2、请在每次提交作业的首页注明完成作业所需的时间；

题目：1、系统方框图如图所示，计算传递函数 $T(s)=Y(s)/R(s)$：





2、假设如图所示运算放大器是理想的，各个参数取值为 $C=1\mu F, R1=167k\Omega, R2=240k\Omega, R3=1k\Omega$, $R4=100k\Omega$，试计算运算放大器电路的传递函数 $G(s)=Vo(s)/Vi(s)$：

3、假设以下两个系统的状态微分方程分别为：

(1) $\dot{x}=\begin{bmatrix}0&1&0\\0&0&1\\-8&-14&-7\end{bmatrix}x+\begin{bmatrix}0\\0\\3\end{bmatrix}u$, $y=\begin{bmatrix}1&0&0\end{bmatrix}x$

(2) $\dot{x}=\begin{bmatrix}1&1&-1\\4&3&0\\-2&1&10\end{bmatrix}x+\begin{bmatrix}0\\0\\1\end{bmatrix}u$, $y=\begin{bmatrix}20&30&10\end{bmatrix}x$

试计算上述系统的传递函数 $G_1(s)$， $G_2(s)$：

4、假设以下两个系统的传递函数分别为：

(1) $G(s)=\dfrac{8}{s^3+7s^2+14s+8}$

(2) $G(s)=\dfrac{8(s+5)}{s^3+12s^2+44s+48}$

试写出上述系统的状态空间模型：

E-mail:zhaoduo@swjtu.edu.cn

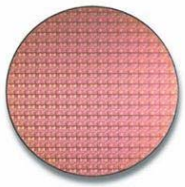
Chapter 1 Introduction to Control System

E-mail:zhaoduo@swjtu.edu.cn

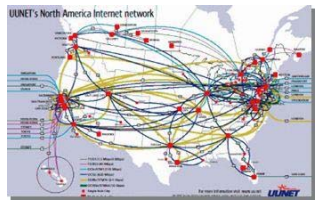
1.1 Introduction

Applications of control systems：

- Aerospace and Transportation 航空航天和运输
- Information and Networks 信息和网络
- Robotics and Intelligent Machines 机器人与智能机器
- Biology and Medicine 生物和医药
- Materials and Processing 材料和加工
- Environment Science, Economy 环境科学、经济和金融
- ……





E-mail:zhaoduo@swjtu.edu.cn

1.1 Introduction

The word "control" has two main meanings.

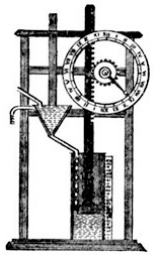
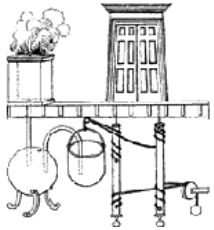
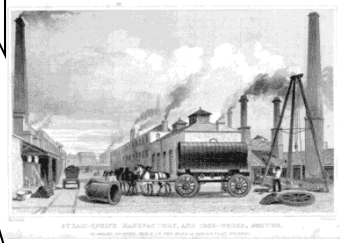
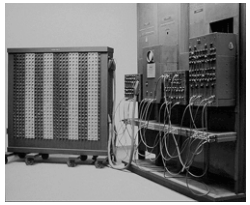
- First, it is understood as the activity of testing or checking that a physical or mathematical device has a *satisfactory behavior*.
- Secondly, to *control* is to *act*, to implement decisions that guarantee that device behaves as desired.

To control is to "out of chaos, comes to order"

> "*… if every instrument could accomplish its own work, obeying or anticipating the will of others … if the shuttle weaved and the pick touched the lyre without a hand to guide them, chief workmen would not need servants, nor masters slaves.*"
>
> Aristotle (384-322 BC), "*Politics*" Book1,Chapter 3

E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

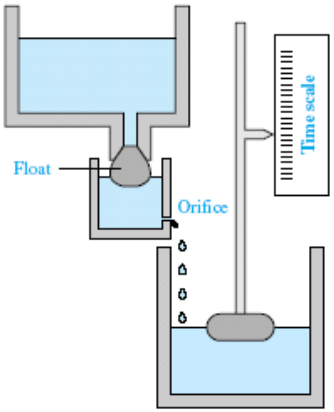
Before 1868	1868-1900	1900-1960	After 1960
Prehistory of Automatic Control	Primitive Period	Classic Period	Modern Period
   Water Clock of the Greeks Arabs and Chinese **300BC-1200AD**	 Industrial Revolution in Europe **1750'**	   Telephone & World Wars **1910-1945**	  Space & Computer Age **1957**

E-mail:zhaoduo@swjtu.edu.cn

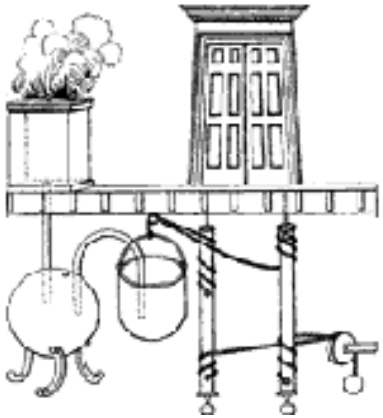
1.2 History of Automatic Control

Before 1868 Prehistory of Automatic Control

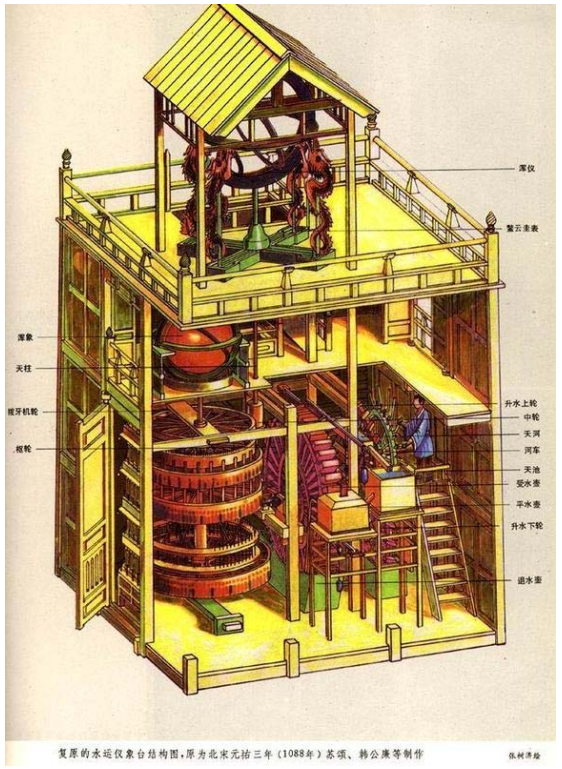
- 300BC Water clocks of the Greeks (Float Regulator) ;
- 800AD Water clocks of the Arabs;
- 1086AD Su Song, Han Gonglian;



Water Clock



Temple Door



水运仪象台

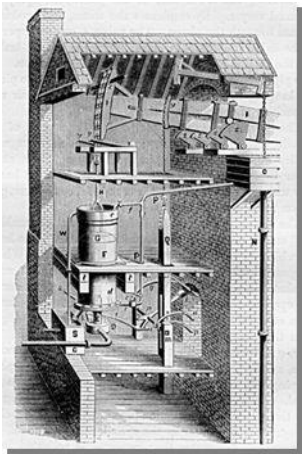
E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

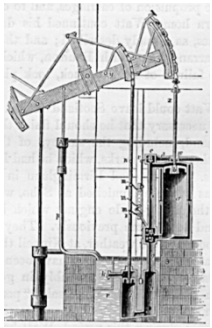
Before 1868 | **1868 - 1900**

- 1788 J. Watt completed the design of the centrifugal fly-ball governor for regulating the speed of the rotary steam engine;

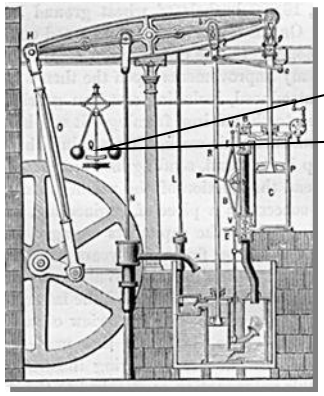
Windmill Fantail 1750



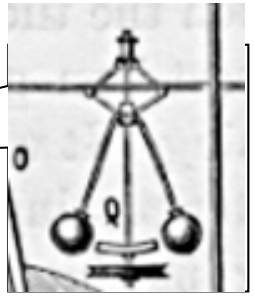
Steam Engine Newcomen 1712



James Watt 1769

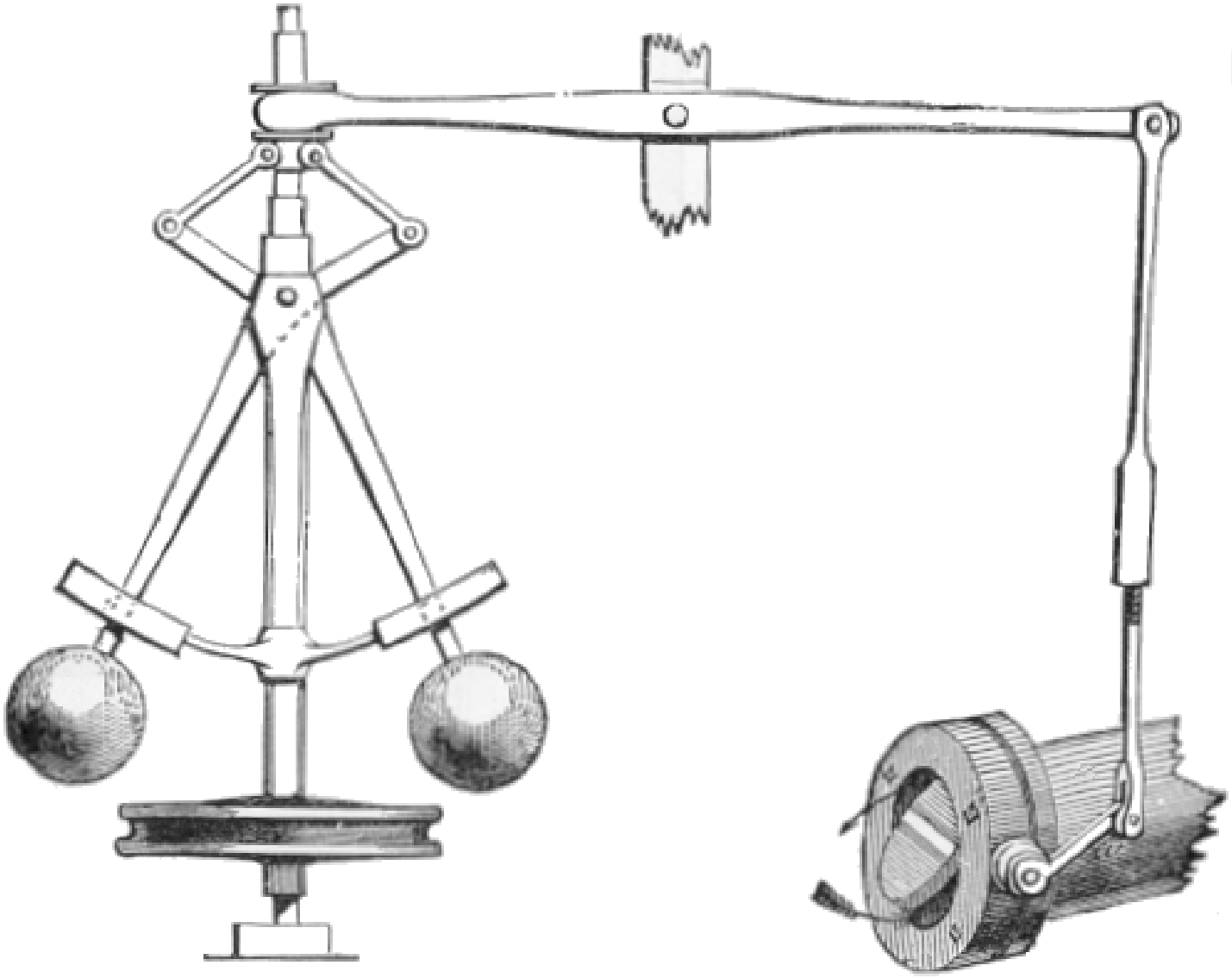


James Watt 1788



Centrifugal Fly-ball Governor

E-mail:zhaoduo@swjtu.edu.cn

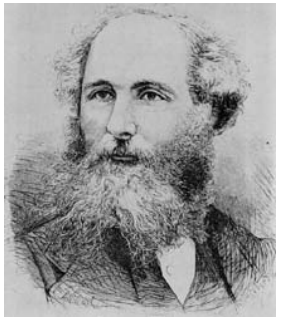


E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

Before 1868 | **1868 - 1900**

- 1840 G.B.Ariy was first to discuss the *instability* of closed loop system, to use the *differential equations* in analysis.
- 1868 J.C.Maxwell formulated a *mathematical theroy* related to control theory using differential equation, **established the theory of control systems**.
- 1877 E.J.Routh and A.Hurwitz 1895 established "*Routh-Hurwitz Stability Criteria*".
- 1892 A.M.Lyapunov studied the stability of nonlinear differential equations using a *generalized notion of energy*.



E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

1868 - 1900 | 1900 - 1960

- 1927 H.S.Black demonstrated the usefulness of *negative feedback*;
- 1932 H.Nyquist derived his *Nyquist stablity criterion* based on the *polar plot* of a complex function;
- 1938 H.W.Bode used the magnitude and phase *frequency response plots* of a complex function;
- 1948 W.R.Evans presented his *root locus* technique.

E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

1868 - 1900 | 1900 - 1960

Classical control theory was naturally couched in the *frequency domain and s-plane.*

Classic Control Theory：

- Transfer Function 传递函数；
- Frequency Response 频率响应法，Root Locus 根轨迹法；

E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

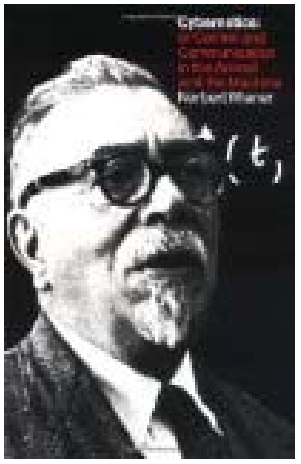
1868 - 1900 | 1900 - 1960

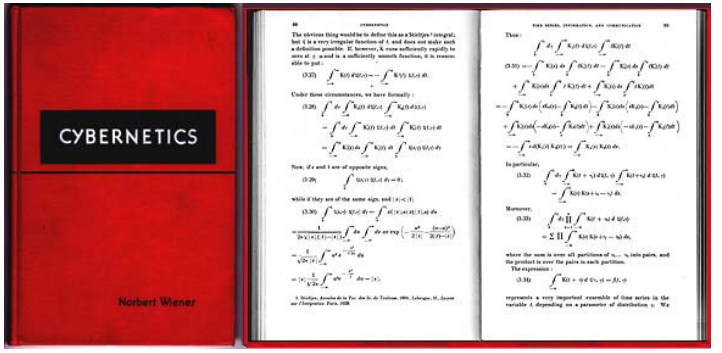
- 1948 N.Wiener

"Cybernetics, or Control and Communication in the Animal and the Machine"

《控制论—或关于在动物与机器中控制和通讯的科学》

首先提出了控制论这个词,这部著作被认为是经典控制理论的辉煌总结。





E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

1868 - 1900 | 1900 - 1960

Major limitations of classical control theory :

- It is primarily applicable for ***Linear time-invariant system*** （LTI system）;
- It is primarily applicable for **Single Input Single Output system** (SISO system).

E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

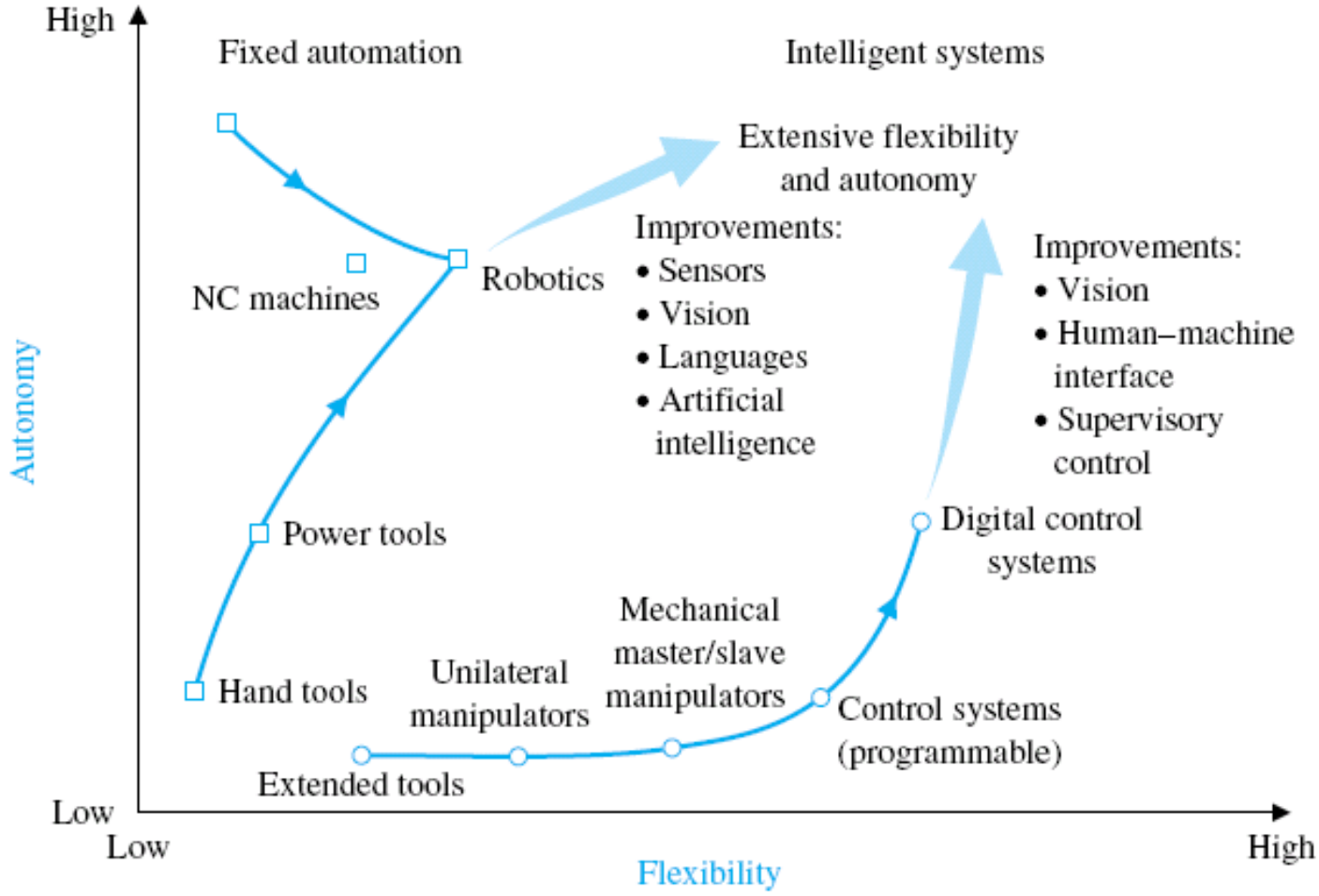
1900 – 1960 | After 1960

- 1957 R.Bllman formulated the *dynamic programming* principle to the optimal control of discrete-time systems;
- 1958 Lev Pontryagin developed the *maximum principle* for solving nonlinear optimal control problems;
- 1960 R.Kalman presented *optimal control of multi-variable systems*, *optimal filtering and estimation theory*;
- Predictive Control, Adaptive Control, Robustness Control ……

E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

Future Opportunities and Challenges 控制系统前瞻



E-mail:zhaoduo@swjtu.edu.cn

1.2 History of Automatic Control

Future Opportunities and Challenges 控制系统前瞻

- Control of systems with both symbolic and continuous dynamics.

  具有符号和连续动态的系统的控制
- Control in distributed, asynchronous, networked environments.

  在分布式、异步网络环境中的控制
- High level coordination and autonomy.

  高级协作与自主控制
- Automatic synthesis of control algorithms, with integrated verification and validation.

  控制算法的自动综合
- Building very reliable systems from unreliable parts.

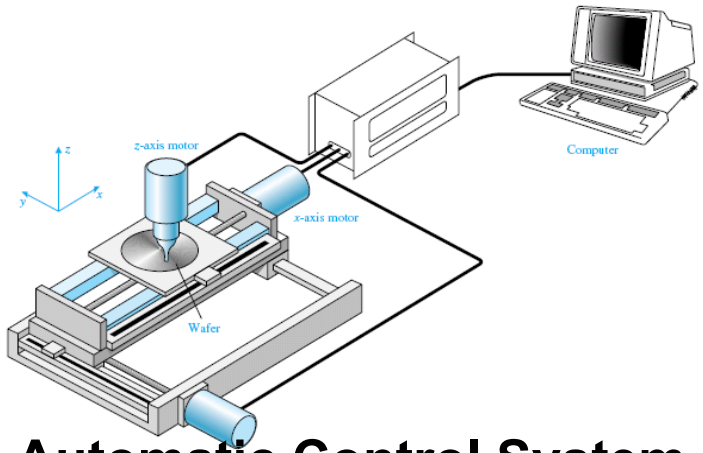
  由不可靠的部件建立可靠的系统

E-mail:zhaoduo@swjtu.edu.cn

1.3 The Basic Mode of Control System

A control system is an interconnection of components forming a system configuration that will provide a desired system response.

控制系统：由相互关联的部件按照一定的结构构成,它能够提供预期的系统响应.



Automatic Control System
自动控制系统

Automatic control system is a system which can fulfill control tasks without involving a person.

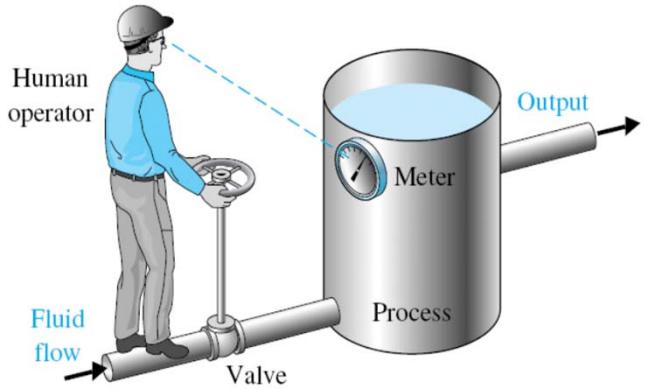
自动控制系统 指没有人的参与,而能完成控制任务的系统。

E-mail:zhaoduo@swjtu.edu.cn

1.3 The Basic Mode of Control System

A control system is an interconnection of components forming a system configuration that will provide a desired system response.

控制系统：由相互关联的部件按照一定的结构构成，它能够提供预期的系统响应.



Manual Control System
手动控制系统

Manual control system is a system which can fulfill control tasks with involving a person.

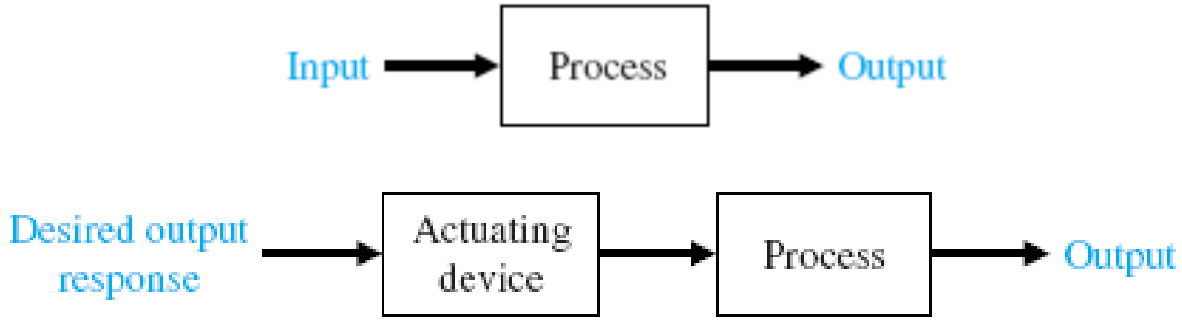
手动控制系统 指在由操作人员参与下完成控制任务的系统。

E-mail:zhaoduo@swjtu.edu.cn

1.3 The Basic Mode of Control System

***Open-Loop Control System*: A system that utilizes a device to control the process without using feedback.**

开环控制系统：在没有反馈的情况下,利用执行机构直接控制受控对象的控制系统.

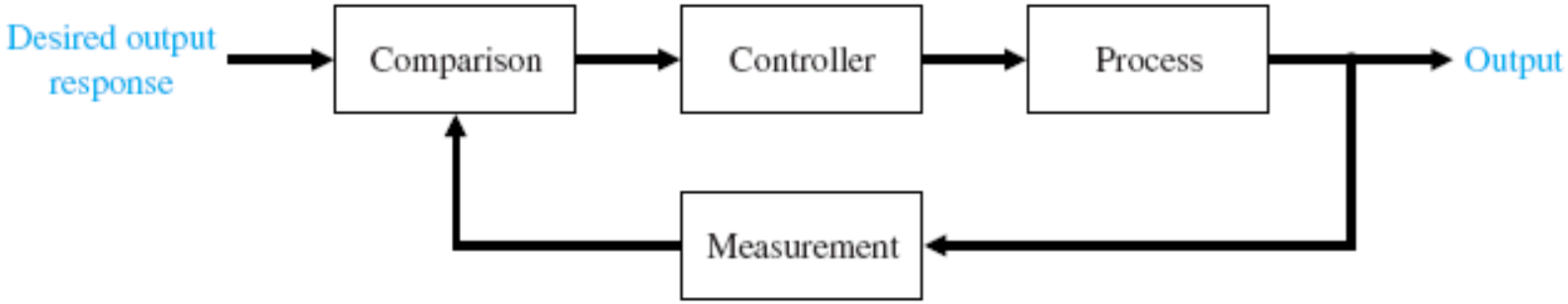


E-mail:zhaoduo@swjtu.edu.cn

1.3 The Basic Mode of Control System

***Closed-Loop Control System*: A system that uses a measurement of the output and compares it with the desired output.**

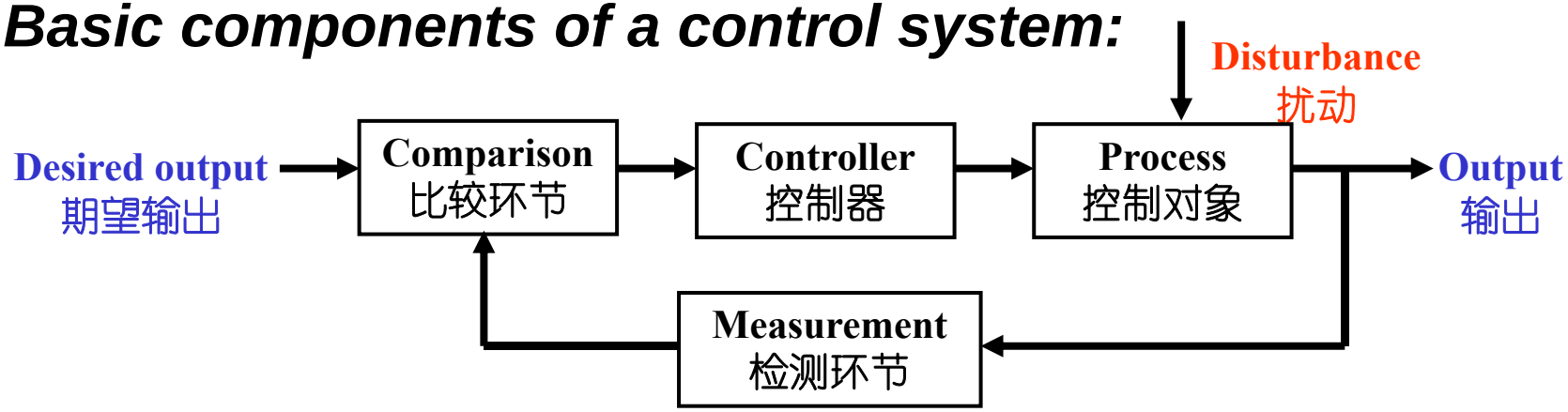
闭环控制系统：对输出进行测量,将此测量信号反馈，并与预期的输出(参考或指令输入)进行比较的系统.



E-mail:zhaoduo@swjtu.edu.cn

1.3 The Basic Mode of Control System

Basic components of a control system:



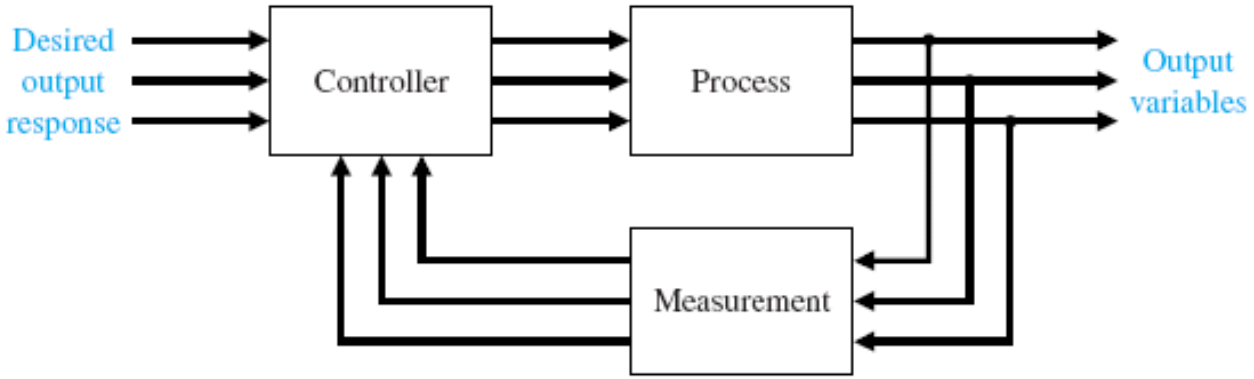
输 出 量: 被控制量
输 入 量: 反映控制系统要求，预先给定的信号
扰　　动: 是一种对系统输出量产生不同作用的信号
控制对象: 被控制的设备、装置或控制过程
控 制 器: 根据系统要求按一定规则产生控制作用
检测环节: 测量输出量，并根据需要进行物理量的转换
比较环节: 比较给定输入与反馈信号的差值，产生偏差信号

E-mail:zhaoduo@swjtu.edu.cn

1.3 The Basic Mode of Control System

Multivariable Control System: A system with more than one input variable or more than one output variable.

多变量控制系统：有多个输入变量或/和多个输出变量的控制系统.



E-mail:zhaoduo@swjtu.edu.cn

1.4 The Classification of Control System

1. According to the character of reference input (desired output) 按照参考输入(期望输出)特征

- *Constant control systems* 恒值控制系统：

  参考输入为定值，控制输出保持在恒定的要求值(克服扰动)；

- *Tracking control systems* 随动控制系统(自动跟踪系统)：

  参考输入预先未知，随时间变化控制输出；控制输出以尽可能小的误差跟随输入的变化；

E-mail:zhaoduo@swjtu.edu.cn

1.4 The Classification of Control System

2. According to the character of mathematic model

按照数学模型的特征——系统的本质分类

- Linear control systems and nonlinear control systems

  线性系统与非线性系统；

- Continuous control systems and discrete control systems

  连续系统与离散系统；

- Single input-output control systems and multiple input multiple output control systems

  单输入单输出系统与多输入多输出系统；

- ……

E-mail:zhaoduo@swjtu.edu.cn

1.4 The Classification of Control System

3. According to the element of the system

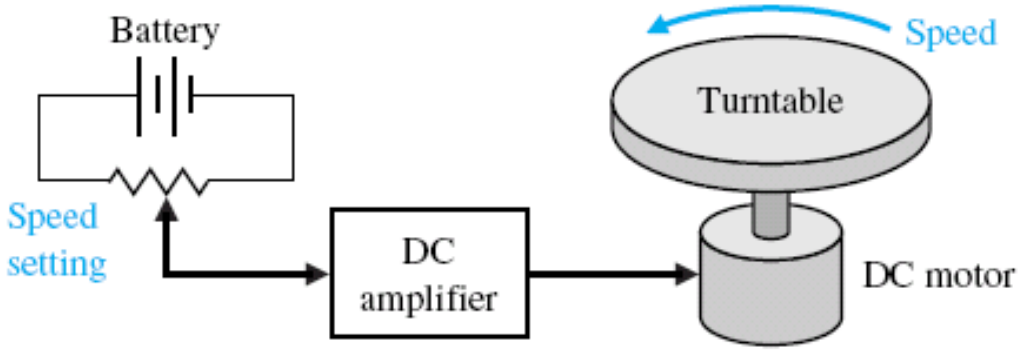
按照组成系统的元件分类

- 电气
- 机械
- 液动
- 气动
- 生物学
- 经济学
- 社会学
- ……

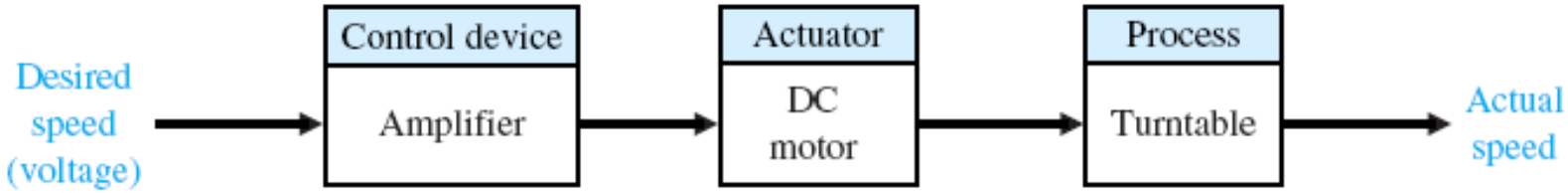
E-mail:zhaoduo@swjtu.edu.cn

1.5 Examples of Control System

- Open-Loop Control System



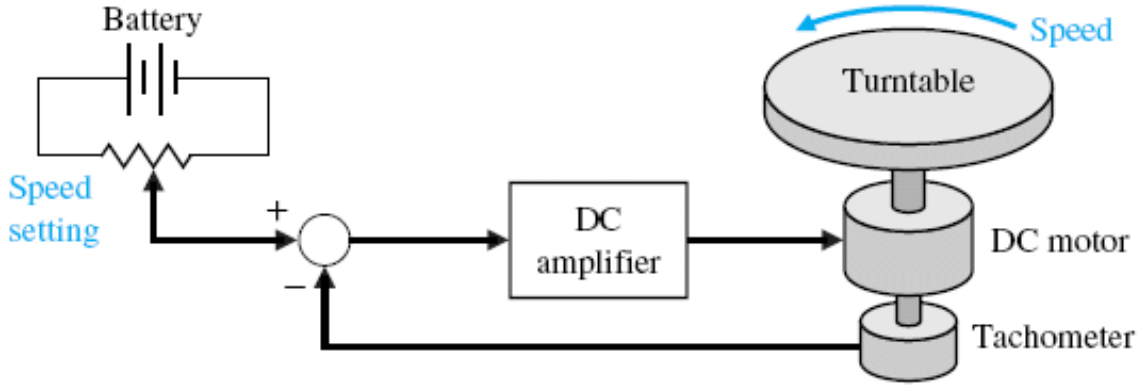
(a) Open-loop Control of the speed of a turntable



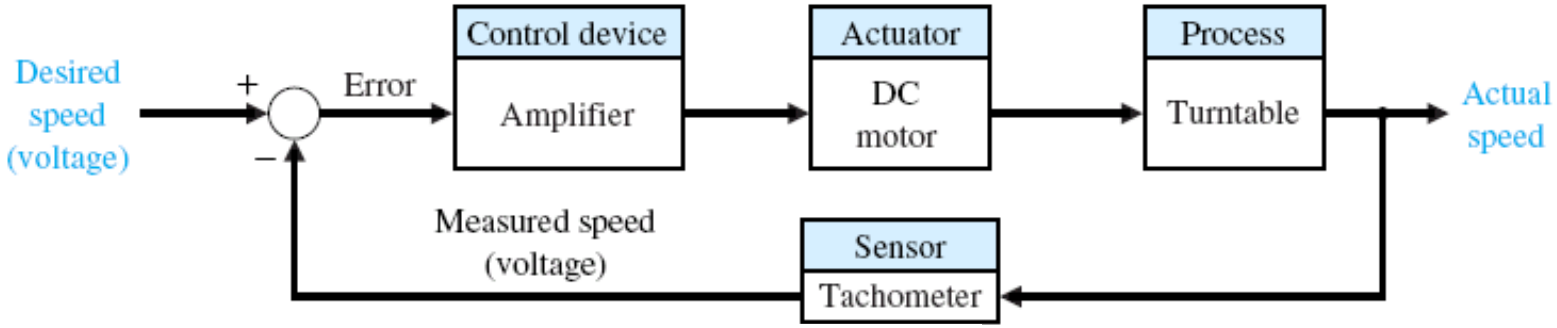
(b) Block Diagram

1.5 Examples of Control System

- Closed-Loop Control System



(a) Close-loop Control of the speed of a turntable

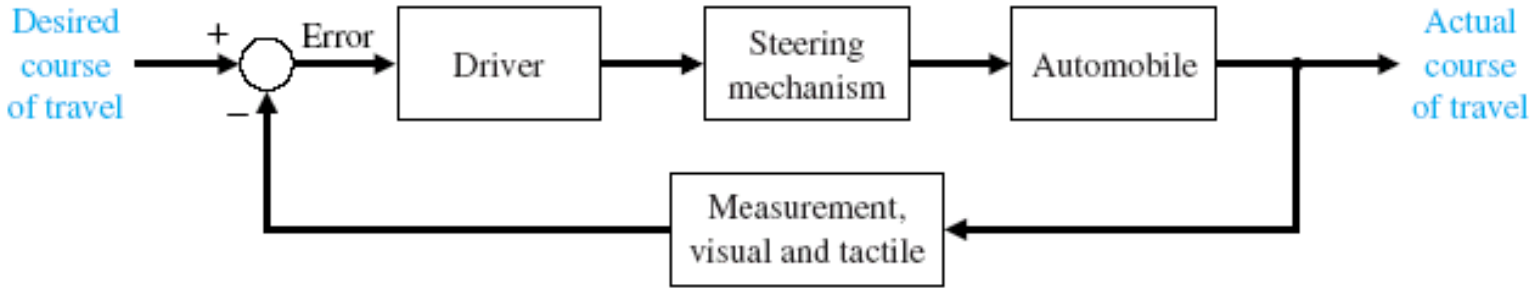


(b) Block Diagram

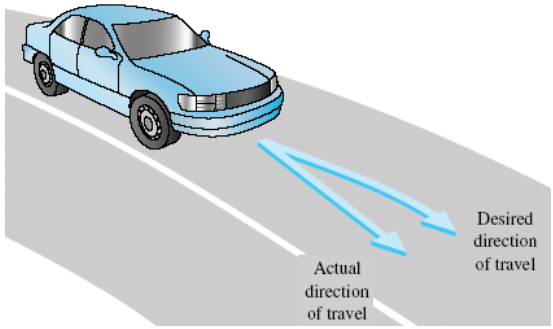
E-mail:zhaoduo@swjtu.edu.cn

1.5 Examples of Control System

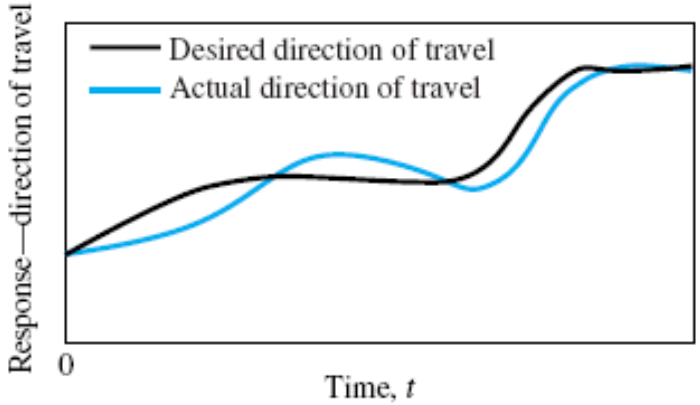
- Automobile Steering Control System



(a) Block Diagram



(b) Measure of Error

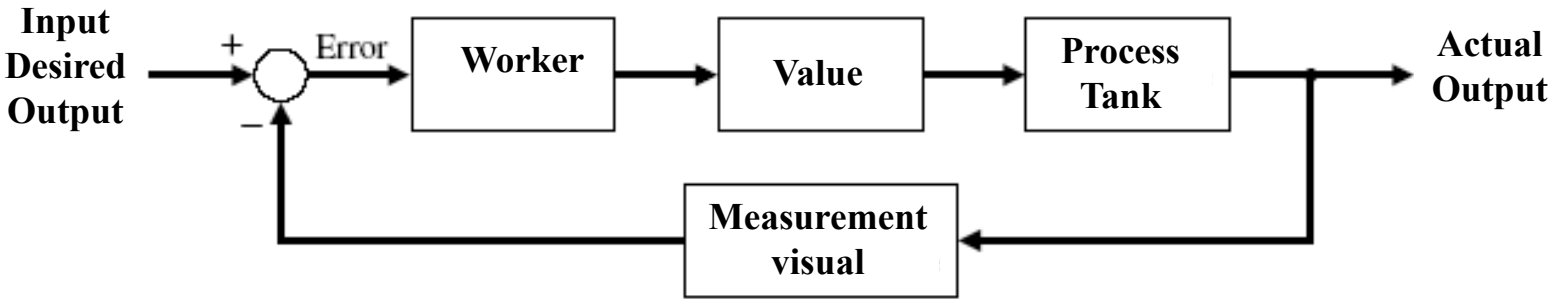


(c) Typical direction-of-travel response

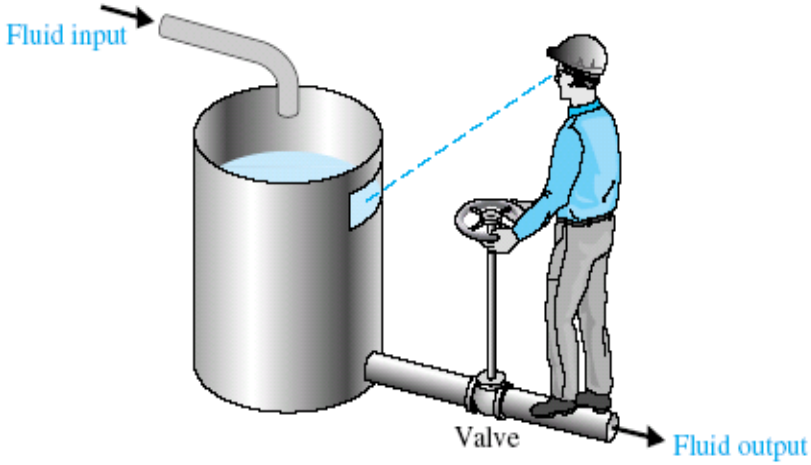
E-mail:zhaoduo@swjtu.edu.cn

1.5 Examples of Control System

Liquid Level Manual Control System



(a) Block Diagram



(b) Manual Control System

E-mail:zhaoduo@swjtu.edu.cn

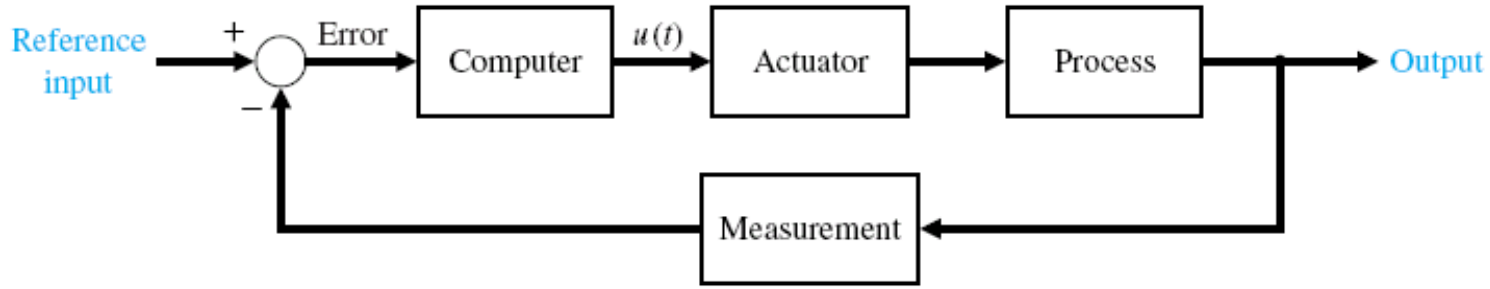
1.5 Examples of Control System

- Differences between Open-loop and Closed-Loop Control System

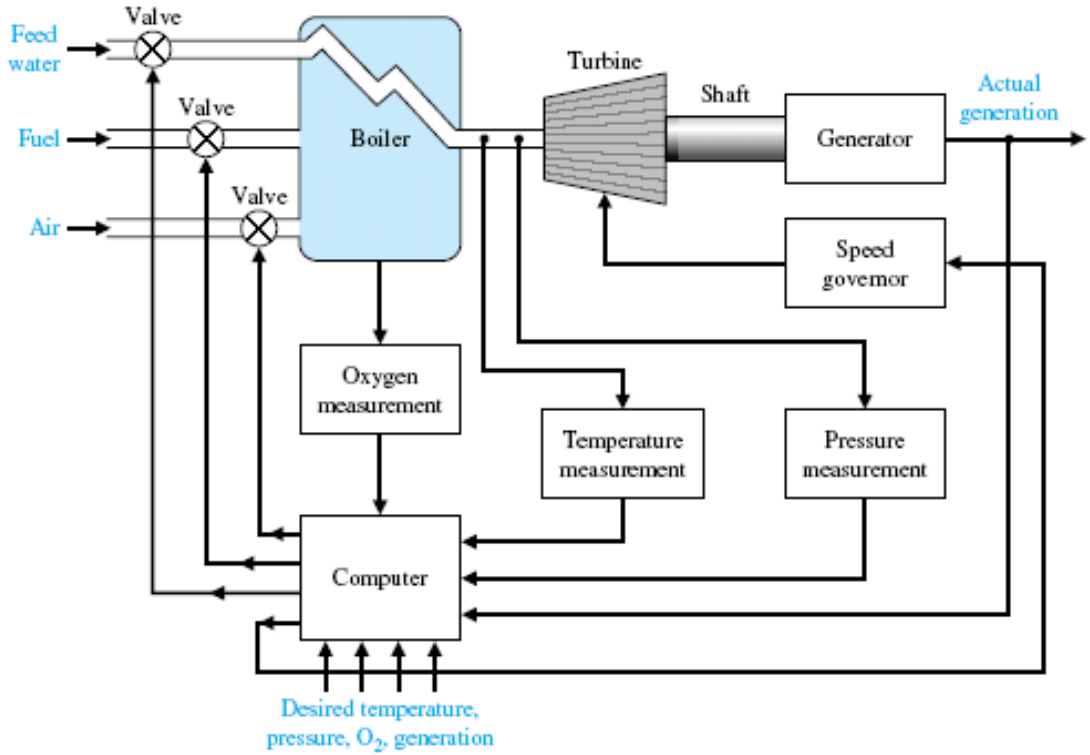
	开环控制	闭环控制
适用范围	系统的输入能预先知道，并且不存在任何扰动（内部、外部）	存在不可预计的扰动和（或）系统中原件参数存在着无法预期的变化
采用反馈	没有反馈	采用了反馈，因而使系统的响应对于外部的干扰和内部系统的参数变化均相当不敏感。
稳定性	容易建造，稳定性问题不是主要问题	始终是一个主要问题，因为闭环系统可能引起超调误差，导致系统产生振荡。
经济性（系统的输出功率大小）	为减少元件数，降低功率采用开环控制	采用较多的元件，其功率较大，制造成本较高

1.5 Examples of Control System

Coordinated Control System



(a) Block Diagram



(b) Coordinated Control System for Boiler Generator

1.6 Basic Requirement & Research Contents of Control System

1. Basic Requirement 基本要求

Stability 稳定：System maintains desired operating point. 有一定的稳定裕量

Performance : System satisfy the requirements for transient and steady-state performance. 满足要求动态响应和稳态响应特性

Robustness: System tolerates perturbations in dynamics.

2. Research Contents 研究内容

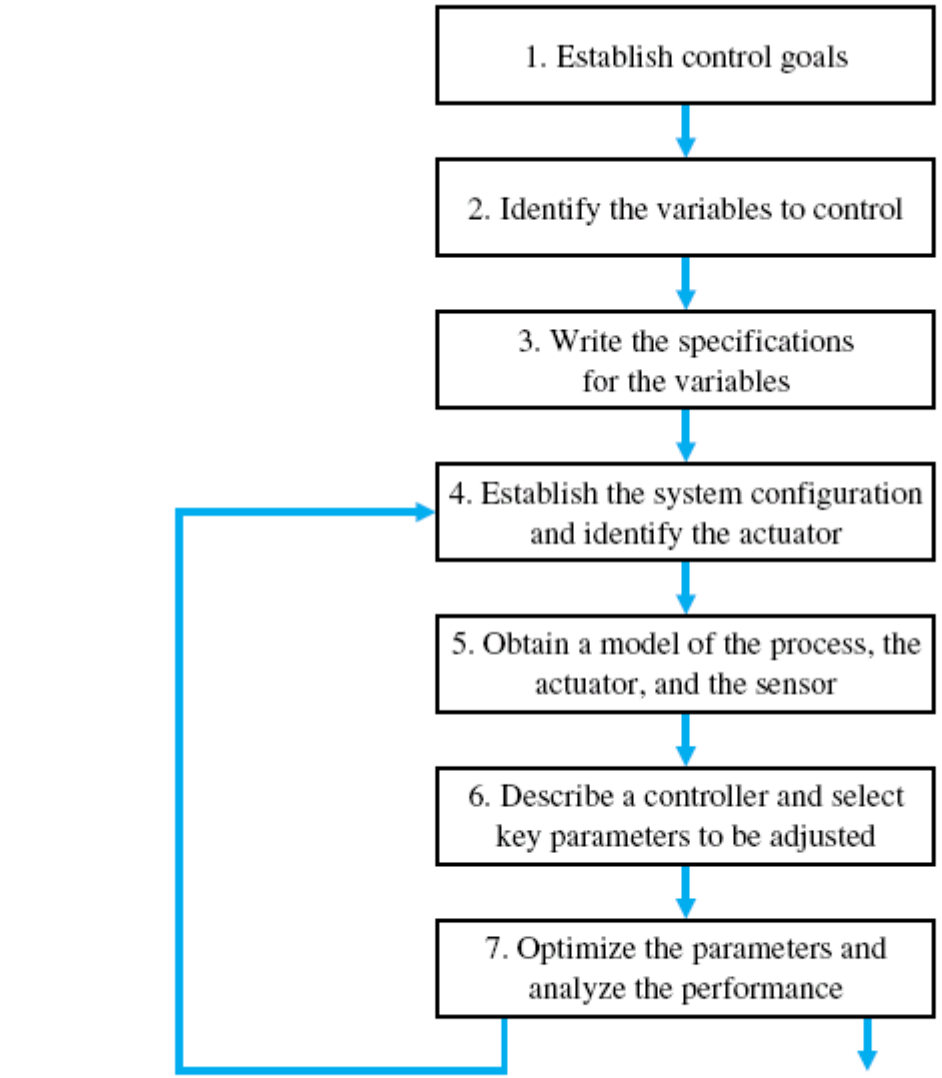
Control System Analysis 控制系统分析

已知系统的结构和参数，分析典型输入信号下系统的响应及指标

Control System Design 系统设计(系统综合)

E-mail:zhaoduo@swjtu.edu.cn

1.7 Design Example

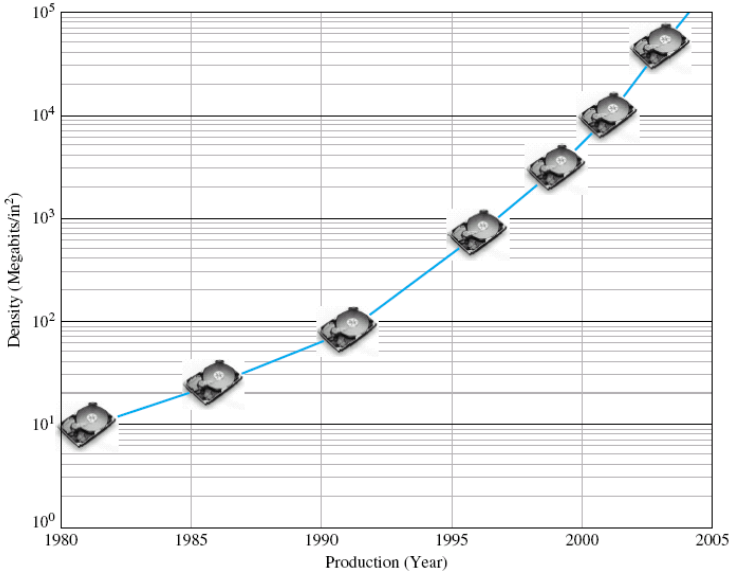


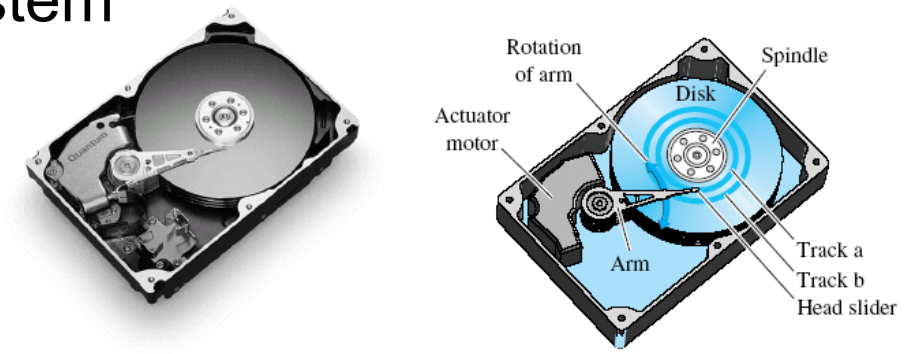
- 确立控制目标
- 确定控制变量
- 拟定设计规范
- 确定系统结构配置
  - 执行结构
  - 传感器
  - 控制器
- 调节系统参数
  - 得到期望性能

E-mail:zhaoduo@swjtu.edu.cn

1.7 Design Example

- Control Goals
  - Control the Reader Head
- Control Variables
  - Position of the Reader Head
- Design Specifications
  - Position Accuracy <1μm
- System Configurations
  - Closed loop Control system
    - Actuator
    - Sensor
    - Controller





A disk drive and a diagram

E-mail:zhaoduo@swjtu.edu.cn

Summary

- Brief history of automatic control.

  介绍了控制理论与技术的发展简况

- Basic elements and the basic forms of control systems.

  介绍了控制系统的基本形式和基本组成环节

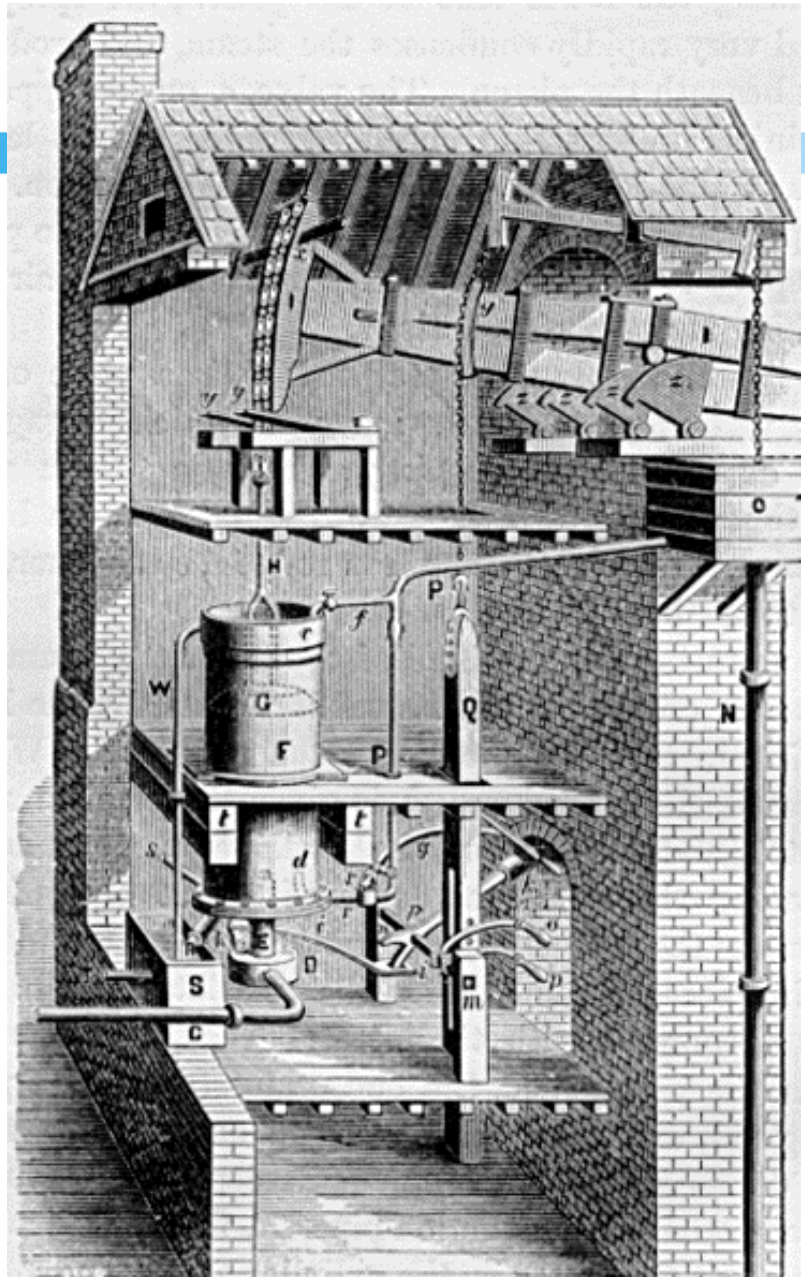
- Classification of control system.

  介绍了控制系统的主要分类

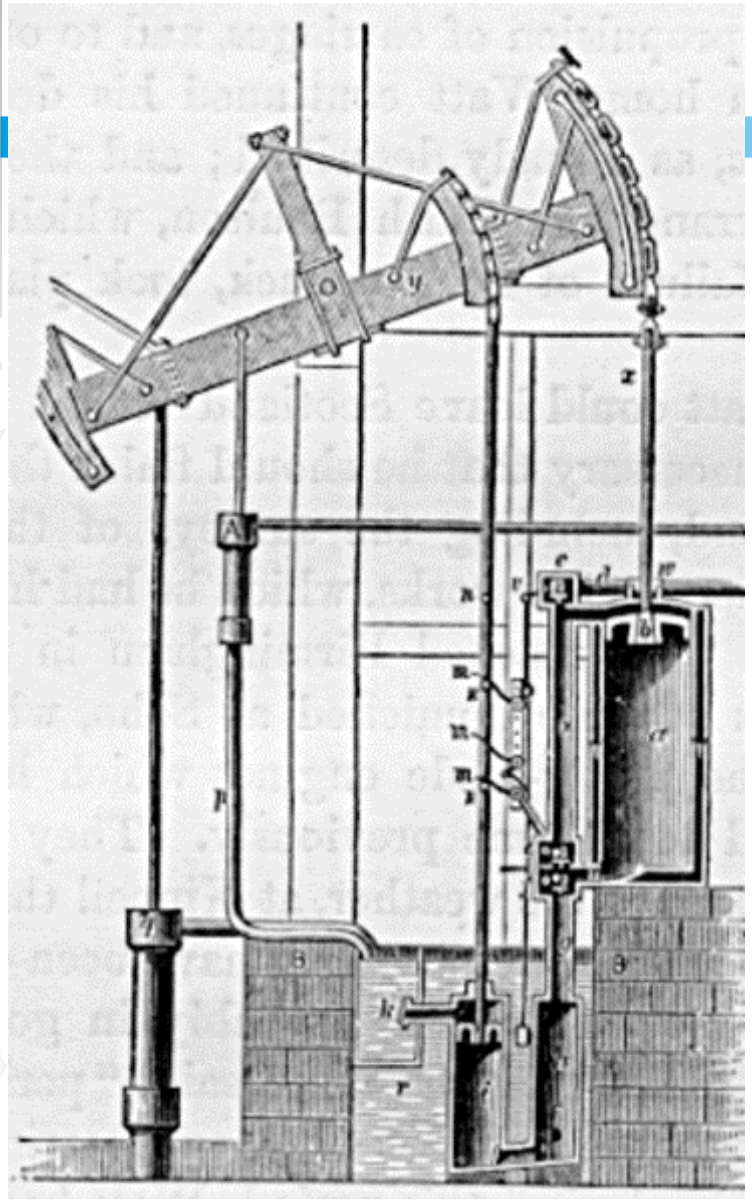
- The main research contents about control systems

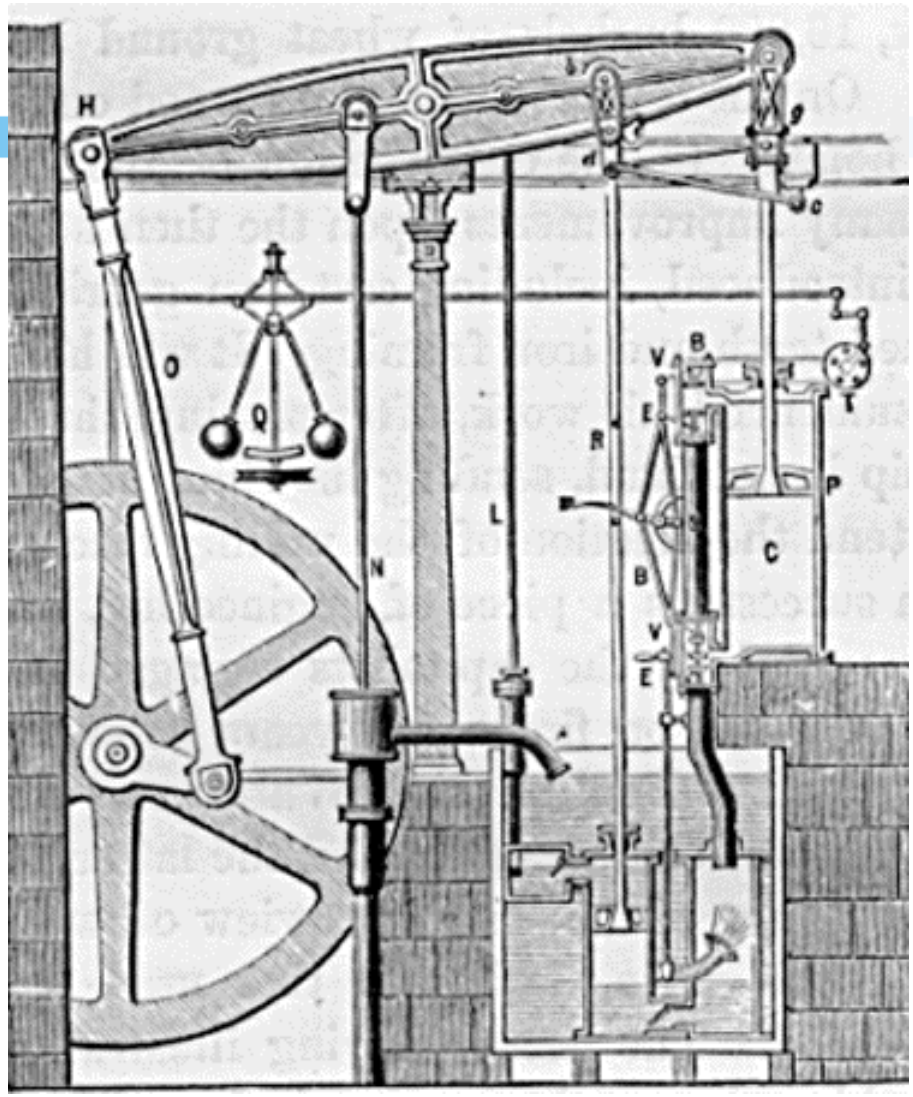
  介绍了对控制系统的基本要求与研究内容

E-mail:zhaoduo@swjtu.edu.cn



E-mail:zhaoduo@swjtu.edu.cn





E-mail:zhaoduo@swjtu.edu.cn