CHAPTER 1
INTRODUCTION TO CONTROL SYSTEM
CONTENTS

1. Basic concepts of control systems
2. Control system: types & effects
3. Control system design process
1. BASIC CONCEPTS OF CONTROL SYSTEMS
Historical Developments

i. Ancient Greece (1 to 300 BC)
   - Water float regulation, water clock

ii. Cornelis Drebbel (17th century)
   - Temperature control

iii. James Watt (18th century)
   - Flyball governor

iv. Late 19th to mid 20th century
   - Modern control theory
The first historical feedback system claimed by Russia was developed by Polzunov in 1765. Polzunov’s water-level float regulator, illustrated in Figure, employs a float that rises and lowers in relation to the water level, thereby controlling the valve that covers the water inlet in the boiler.
Water Clock
Further evolution in automation was enabled by advancements in control theory traced back to the Watt flyball governor of 1769. The flyball governor, illustrated in Figure, was used to control the speed of a steam engine.

Employing a measurement of the speed of the output shaft and utilizing the motion of the flyball to control the valve, the amount of steam entering the engine is controlled. As the speed of the engine increases, the metal spheres on the governor apparatus rise and extend away from the shaft axis, thereby closing the valve. This is an example of a feedback control system where the feedback signal and the control actuation are completely coupled in the mechanical hardware.
Component or process to be controlled can be represented by a block diagram.

The input-output relationship represents the **cause and effect** of the process.

Control systems can be classified into two categories:

i. Open-loop control system

ii. Closed-loop feedback control system
Classification:

- An open-loop control system utilizes an actuating device to control the process directly without using feedback.

- A closed-loop feedback control system uses a measurement of the output and feedback of the output signal to compare it with the desired output or reference.

Single Input Single Output (SISO) System
Multi Input Multi Output (MIMO) System
General Control System
Control System Components

i. System, plant or process
   ■ To be controlled

ii. Actuators
    ■ Converts the control signal to a power signal

iii. Sensors
    ■ Provides measurement of the system output

iv. Reference input
    ■ Represents the desired output
2. CONTROL SYSTEMS
Examples:

- (a) Residential heating and air-conditioning systems controlled by a thermostat
- (b) Manual control:
  (i) Opening or closing of a window for regulating air temperature or air quality
  (ii) Activation of a light switch to regulate the illumination in a room
  (iii) Human controlling the speed of an automobile by regulating the gas supply to the engine
- (c) Automatic traffic control (signal) system at roadway intersections
- (d) Control system which automatically turns on a room lamp at dusk, and turns it off in daylight
- (e) Automatic hot water heater
- (f) Environmental test-chamber temperature control system
- (g) An automatic positioning system for a missile launcher
- (h) An automatic speed control for a field-controlled dc motor
- (i) The attitude control system of a typical space vehicle
- (j) Automatic position-control system of a high speed automated train system
- (k) Human heart using a pacemaker
- (l) An elevator-position control system used in high-rise multilevel buildings.
Control System

- **Control** is the process of causing a system variable to conform to some desired value.
- **Manual control** → **Automatic control** (involving machines only).
- A **control system** is an interconnection of components forming a system configuration that will provide a desired system response.
Manual Vs Automatic Control

- **Control** is a process of causing a system variable such as temperature or position to conform to some desired value or trajectory, called reference value or trajectory.

- For example, **driving a car implies controlling the vehicle to follow the desired path** to arrive safely at a planned destination.
  
  i. If you are **driving the car yourself**, you are performing manual control of the car.
  
  ii. If you use **design a machine**, or use a computer to do it, then you have built an automatic control system.
EXAMPLES OF MODERN CONTROL SYSTEM

a. Transportation
b. Temperature Control
c. Process Industry
d. Manufacturing Industry
e. Homes
Objective: To control direction and speed of car

Outputs: Actual direction and speed of car

Control inputs: Road markings and speed signs

Disturbances: Road surface and grade, wind, obstacles

Possible subsystems: The car alone, power steering system, breaking system
Transportation cont..

- **Functional block diagram:**

  - Desired course of travel
  - Error
  - Measurement, visual and tactile
  - Driver
  - Steering Mechanism
  - Automobile
  - Actual course of travel

- **Time response:**

  ![Time response graph]
Consider using a radar to measure distance and velocity to autonomously maintain distance between vehicles.

Automotive: Engine regulation, active suspension, anti-lock breaking system (ABS)

Steering of missiles, planes, aircraft and ships at sea.
b. Temperature Control

- Schematic diagram of temperature control of an electric furnace.
- The temperature in the electric furnace is measured by a thermometer, which is analog device.
- The analog temperature is converted to a digital temperature by an A/D converter.
- The digital temperature is fed to a controller through an interface.
- This digital temperature is compared with the programmed input temperature, and if there is any error, the controller sends out a signal to the heater, through an interface, amplifier and relay to bring the furnace temperature to a desired value.
c. Process Industry

- Control used to regulate level, pressure and pressure of refinery vessels.

- For steel rolling mills, the position of rolls is controlled by the thickness of the steel coming off the finishing line.

Coordinated control system for a boiler-generator.
d. Manufacturing Industry

- Consider a **three-axis control system** for inspecting individual semiconducting wafers with a highly sensitive camera.
e. Homes

i. CD Players

- The position of the laser spot in relation to the microscopic pits in a CD is controlled.

ii. Air-Conditioning System

- Uses thermostat and controls room temperature.
DESIGN EXAMPLES
Turntable Speed Control

- **Application:** CD player, computer disk drive
- **Requirement:** Constant speed of rotation
- **Open loop control system:**

![Block diagram representation](image)

- **Block diagram representation:**
Turntable Speed Control cont..

- **Closed-loop control system:**

![Block diagram representation of a closed-loop control system for turntable speed control.](image1.png)

- **Block diagram representation:**

![Block diagram representation of a closed-loop control system for turntable speed control.](image2.png)
SEQUENTIAL DESIGN EXAMPLE
Disk Drive Read System

- **Goal of the system**: Position the reader head in order to read data stored on a track.
- **Variables to control**: Position of the reader head
Disk Drive Read System

- **Specification:**
  1. Speed of disk: 1800 rpm to 7200 rpm
  2. Distance head-disk: Less than 100nm
  3. Position accuracy: 1 µm
  4. Move the head from track ‘a’ to track ‘b’ within 50ms

- **System Configuration:**

![Diagram of disk drive read system](image)
Response Characteristics

- **Transient response:**
  - Gradual change of output from initial to the desired condition

- **Steady-state response:**
  - Approximation to the desired response

- For example, consider an elevator rising from ground to the 4\textsuperscript{th} floor.
Control System Classification

Missile Launcher System

Open-Loop Control System
Control System Classification

Missile Launcher System

Closed-Loop Feedback Control System
Purpose of Control Systems

i. Power Amplification (Gain)
   - Positioning of a large radar antenna by low-power rotation of a knob

ii. Remote Control
    - Robotic arm used to pick up radioactive materials

iii. Convenience of Input Form
    - Changing room temperature by thermostat position

iv. Compensation for Disturbances
    - Controlling antenna position in the presence of large wind disturbance torque
EXAMPLES: MECHATRONIC SYSTEM
a. Hybrid Fuel Vehicles
b. Wind Power
3. CONTROL SYSTEMS DESIGN PROCESS
Control System Design Process

1. Establish control goals
2. Identify the variables to control
3. Write the specifications for the variables
4. Establish the system configuration and identify the actuator
5. Obtain a model of the process, the actuator and the sensor
6. Describe a controller and select key parameters to be adjusted
7. Optimize the parameters and analyze the performance

If the performance meet the specifications, then finalize design.

If the performance does not meet specifications, then iterate the configuration and actuator.