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MEE 418: Control systems

Lecture 0
Introduction

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Federal University of Technology, Minna

1

Outline

- Course Outline
- Recommended Books
- Prerequisites of the subject
- Basic Definitions
- Types of Control Systems
- Examples

2

Course information

Lecture Period:

- Thursdays: 8.00am to 11.00 am SIPET Building Rm 213

Required Textbook:

- *Control systems engineering, I. J. Nagarath & M. Gopal. New Age International Publishers, 4th Edition.*
- *Modern Control Systems, Richard C. Dorf and Robert H. Bishop*, Prentice Hall, 12th edition, 2010, ISBN-10: 0-13-602458-0.

3

Main components of the course

- Lectures (about 40 lectures)
- Quiz
- Midterm break (don't know when it will be)
- Final (Final exam period)
- Grading:
  - Homework (20%), Test (20%) Exam 1 (60%)
  - Homework will be due in one week from the day it is assigned

4

Some success tips

- Regular attendance
- Print out and bring lecture slides to the lecture (if available).
- Actively participate "Exercises" in each lecture.
- Do homework every week.
- Read the textbook and the slides.
- Make use of instructor's office hours.

5

Math Prerequisites

- Complex Numbers: Add, Subtract, Multiply, Divide
- Linear Algebra: Matrix Multiply, Inverse, Sets of Linear Eq.
- Linear Ordinary Differential Equations
- Laplace Transform to Solve ODE's
- Linearization
- Logarithms
- Modelling of Physical Systems: Mechanical, Electrical, Thermal, Fluid
- Dynamic Responses: 1st and 2nd Order Systems of ODE's

6

Course synopsis

Classical Control
- Introduction to Control System
- System Modelling
  - Transfer Function
  - Block Diagrams
  - Signal Flow Graphs
- System Analysis
  - Time Domain Analysis
  - Frequency Domain Analysis
    - Bode Plots, Nyquist Plots
  - Routh Stability Criteria
- Root Locus
- System Design
  - Compensation Techniques
  - PID Control

7

What is Control System?

- **A system:**

  an arrangement of set/collections of things that are connected or related in such a manner as to form entire/whole unit. An interconnection of elements and devices for a desired purpose. A system may not all be physical, e.g., biological, economic, socio-economic or management systems.

  Physical system:

  An arrangement of physical components connected or related in such a manner as to form and/or act as an entire unit in service of an objective. E.g. Electronic amplifier (composed of many components), the governing mechanism of a steam turbine or a communications satellite orbiting the earth.
- **Control**: to regulate, direct or command.
- **Control System** therefore

  (1) is a device, or set of devices to manage, command, direct or regulate the behaviour of other device(s) or system(s).

  (2) The means by which any quantity of interest in a machine , mechanism or other equipment is maintained or altered in accordance with a desired manner.

  (3): An interconnection of components forming a system configuration that will provide a desired response.

8

Terminologies and Definitions

Input: a stimulus, excitation applied to a system from an external energy source usually to make the system respond in a desired manner. Usually the input is the desired response expected from the system we intend to control.

Output: the actual response of the system. This may (or may not) be the desired response implied by the input.

Process – The device, plant, or system under control. The input and output relationship represents the cause-and-effect relationship of the process and which characterizes the process.

9

Definitions

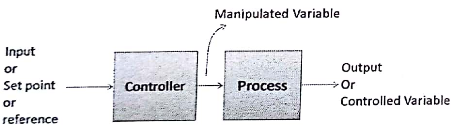
Controlled Variable– It is the quantity or condition that is measured and Controlled. Normally *controlled variable* is the output of the control system.

Manipulated Variable– It is the quantity of the condition that is varied by the controller so as to affect the value of *controlled variable*.

Control – Control means measuring the value of *controlled variable* of the system and applying the *manipulated variable* to the system to correct or limit the deviation of the measured value from a desired value.

10

Definitions



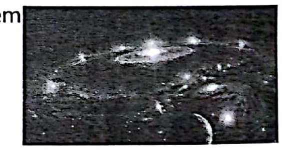
Disturbances– A disturbance is a signal that tends to adversely affect the value of the system. It is an unwanted input of the system.

- If a disturbance is generated within the system, it is called *internal disturbance*. While an *external disturbance* is generated outside the system.

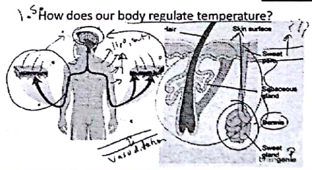
11

Types of Control System

- Natural Control System
  - Universe
  - Human Body



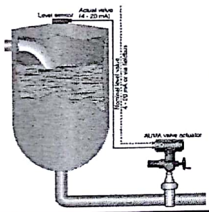
How does our body regulate temperature?

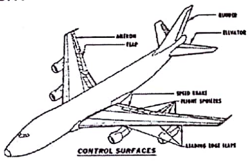


12

Types of Control System

- Manmade Control System
  - Aeroplanes
  - Chemical Process

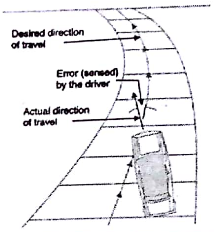


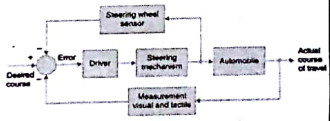


13

Types of Control System

- Man-made and Natural (compound) Control System:

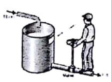




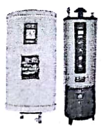
14

Types of Control System

- Manual Control Systems
  - Room Temperature regulation Via Electric Fan
  - Water Level Control



- Automatic Control System
  - Home Water Heating Systems (Geysers)
  - Room Temperature regulation Via A.C
  - Human Body Temperature Control



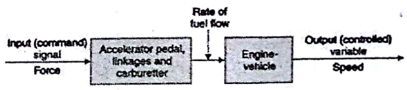
15

Classification of Control System

Open-Loop Control Systems

Open-Loop Control Systems utilize a controller or control actuator to obtain the desired response.

- the control action is independent of the Output.
- In other words output is neither measured nor fed back.



Open—loop control system (without a feedback)

Examples:- **Washing Machine, Toaster, Electric Fan, microwave oven, e.t.c**

16

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Classification of Control System

Open-Loop Control Systems

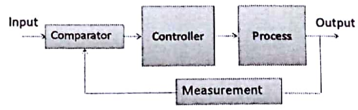
- Since in open loop control systems reference input is not compared with measured output, for each reference input there is fixed operating condition. Therefore, the accuracy of the system depends on *calibration*.
- The performance of open loop system is severely affected by the presence of disturbances, or variation in operating/ environmental conditions.

17

Types of Control System

Closed-Loop Control Systems

Closed-Loop Control Systems utilizes feedback to compare the actual output to the desired output response.



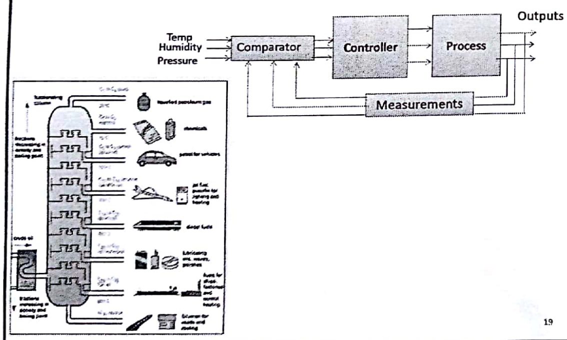
Closed-loop feedback control system (with feedback).

Examples:- **Refrigerator, Electric Iron, Air conditioner**

18

Types of Control System

Multivariable Control System

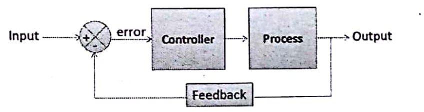


19

Types of Control System

Feedback Control System

- A system that maintains a prescribed relationship between the output and some reference input by comparing them and using the difference (i.e. error) as a means of control is called a feedback control system.



- Feedback can be *positive* or *negative*.

20

Types of Control System

Characteristics of Feedback Control System

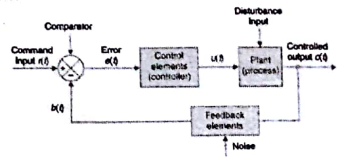
The most important features of the FBCS is the presence of a Feedback which is responsible for;

- Increased accuracy: measured by the ability to produce the output intended by the input through reduction in the effect of disturbances input.
- Reduce the sensitivity of the output-input ratio variations in system characteristics.
- Reduce the effect of nonlinearities and changes in plant parameters.
- Increase the operational bandwidth i.e., the range of frequency of input over which the system will respond satisfactorily.
- Tendency towards uncontrolled behaviour—instability.

21

The control problem

The basic block diagram

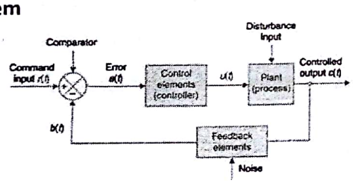


This basic control loop with negative feedback responds to reduce the error between the command input (desired output) and the controlled output. Notice the presence of the disturbance input—the load disturbance (such as that resulting from inaccuracy of the model, and the noise-such as introduced by inaccuracy in measurement process.

22

The control problem

The basic block diagram



Generally, a controller (or a filter) is required to process the error signal such that the overall system satisfies certain criteria specifications. Some of these criteria are:

1. Reduction in effect of disturbance signal.
2. Reduction in steady-state errors.
3. Transient response and frequency response performance.
4. Sensitivity to parameter changes.

23

The control problem

Generally, a controller (or a filter) is required to process the error signal such that the overall system satisfies certain criteria specifications. Some of these criteria are:

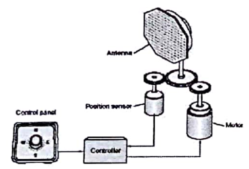
1. Choice of feedback sensor(s) to get a measure of the controlled output.
2. Choice of actuator to drive (manipulate) the plant like opening or closing a valve, adjusting the excitation or armature voltage of a motor.
3. Developing mathematical models of plant, sensor and actuator.
4. Controller design based on models developed in step 3 and the specified criteria.
5. Simulating system performance and fine tuning.
6. Iterate the above steps, if necessary.
7. Building the system or its prototype and testing.

24

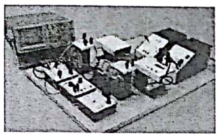
Types of Control System

Servo System

- A Servo System (or servomechanism) is a feedback control system in which the output is some mechanical position, velocity or acceleration.



Antenna Positioning System



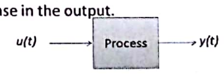
Modular Servo System (MS150)

25

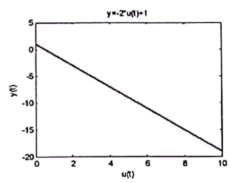
Types of Control System

Linear Vs Nonlinear Control System

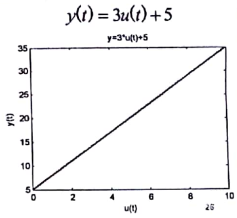
- A Control System in which output varies linearly with the input is called a linear control system. i.e., the increase in input brings about corresponding increase in the output.



$y(t) = -2u(t) + 1$



$y(t) = 3u(t) + 5$

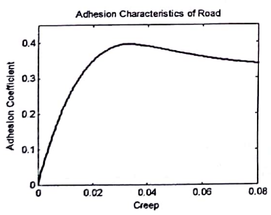


26

Types of Control System

Linear Vs Nonlinear Control System

- When the input and output has nonlinear relationship the system is said to be nonlinear.



27

Types of Control System

Time invariant vs Time variant

- When the characteristics of the system do not depend upon time itself then the system is said to time invariant control system.

$$y(t) = -2u(t) + 1$$

- Time varying control system is a system in which one or more parameters vary with time.

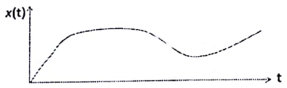
$$y(t) = 2u(t) - 3t$$

28

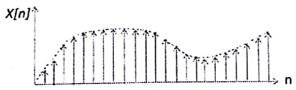
Types of Control System

Continuous Data Vs Discrete Data System

- In continuous data control system all system variables are function of a continuous time t.



- A discrete time control system involves one or more variables that are known only at discrete time intervals.

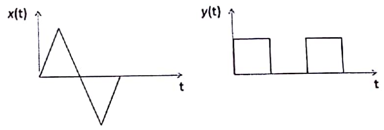


29

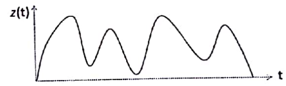
Types of Control System

Deterministic vs Stochastic Control System

- A control System is deterministic if the response to input is predictable and repeatable.

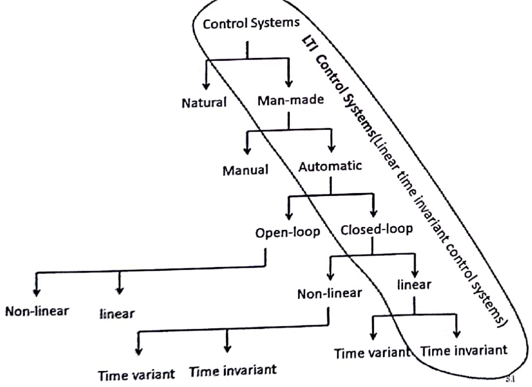


- If not, the control system is a stochastic control system



30

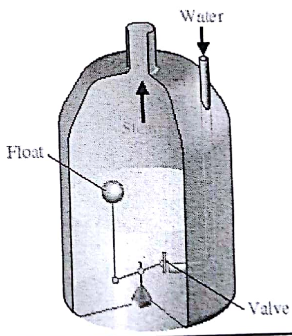
Classification of Control Systems



31

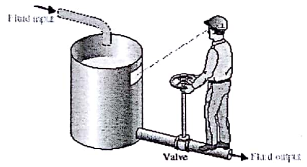
Examples of Control Systems

Water-level float regulator



32

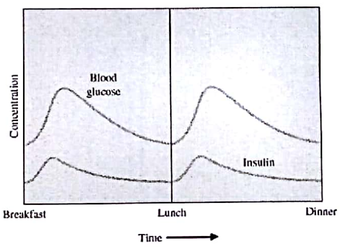
Examples of Control Systems



A manual control system for regulating the level of fluid in a tank by adjusting the output valve. The operator views the level of fluid through a port in the side of the tank.

35

Examples of Modern Control Systems



The blood glucose and insulin levels for a healthy person.

34

35