AST 303 (Control Systems)

Lec. Mohammad Mehdi GOMROKI

Introduction to Control Systems

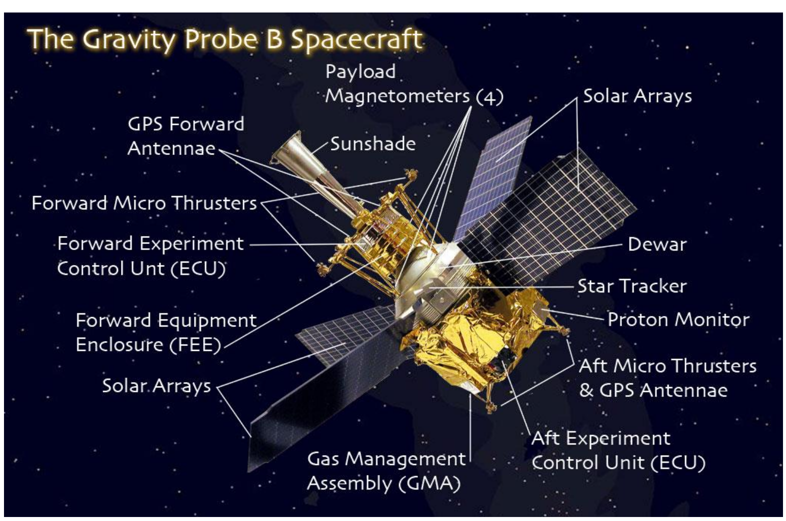
Why Learn Control?

Why Learn Control?

Faculty of Aeronautics and Astronautics

3

Why Learn Control?



Faculty of Aeronautics and Astronautics

4

Introduction

- Control theories commonly used today are **classical control theory** (also called conventional control theory), **modern control theory**, and **robust control theory**. This course presents comprehensive treatments of the analysis and design of control systems based on the classical control theory.
- Automatic control is essential in any field of engineering and science. Automatic control is an important and integral part of space-vehicle systems, robotic systems, modern manufacturing systems, and any industrial operations involving control of temperature, pressure, humidity, flow, etc. It is desirable that most engineers and scientists are familiar with theory and practice of automatic control.
- Mathematical background materials related to **Laplace Transforms**, **Partial Fraction Expansion** and **Vector-Matrix Algebra** are presented separately in appendixes A, B, and C at the end of the text book.

Introduction

Definitions. Before we can discuss control systems, some basic terminologies must be defined.

Controlled Variable and Control Signal or Manipulated Variable. The **controlled variable** is the quantity or condition that is measured and controlled. The **control signal or manipulated variable** is the quantity or condition that is varied by the controller so as to affect the value of the controlled variable. Normally, **the controlled variable is the output of the system**. Control means measuring the value of the controlled variable of the system and applying the control signal to the system to correct or limit deviation of the measured value from a desired value.

Plants. A plant may be a piece of equipment, perhaps just a set of machine parts functioning together, the purpose of which is to perform a particular operation. In this course, we shall call any physical object to be controlled (such as a mechanical device, a heating furnace, a chemical reactor, or a spacecraft) a plant.

Introduction

Processes. In this course we shall call any operation to be controlled a process. Examples are chemical, economic, and biological processes.

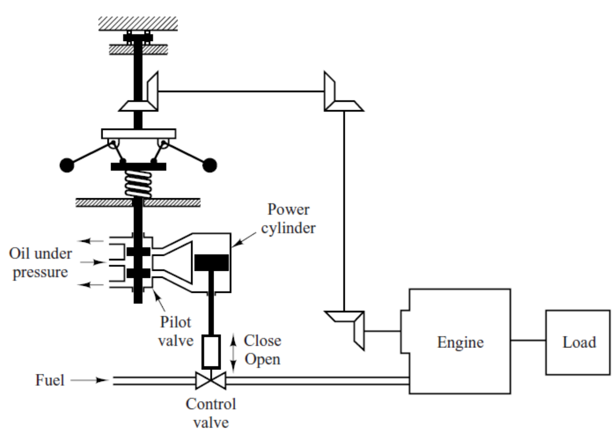
Systems. A system is a combination of components that act together and perform a certain objective.

Disturbances. A disturbance is a signal that tends to adversely affect the value of the output of a system. If a disturbance is generated within the system, it is called internal, while an external disturbance is generated outside the system and is an input.

Feedback Control. Feedback control refers to an operation that, in the presence of disturbances, tends to reduce the difference between the output of a system and some reference input and does so on the basis of this difference.

Examples of Control Systems

Speed Control System. The basic principle of a Watt's speed governor for an engine is illustrated in the schematic diagram of following Figure.

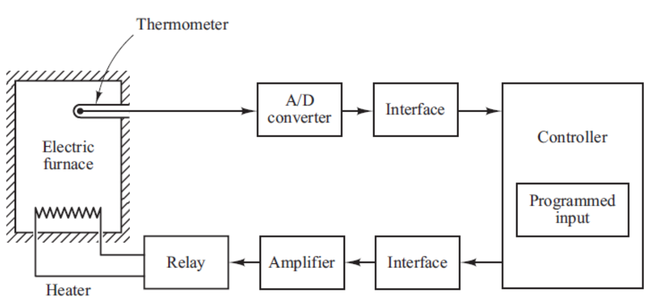


Examples of Control Systems

In this speed control system, the plant (controlled system) is the engine and the controlled variable is the speed of the engine. The difference between the desired speed and the actual speed is the error signal. The control signal (the amount of fuel) to be applied to the plant (engine) is the actuating signal. The external input to disturb the controlled variable is the disturbance. An unexpected change in the load is a disturbance.

Examples of Control Systems

Temperature Control System. Following Figure shows a schematic diagram of temperature control of an electric furnace. The temperature in the electric furnace is measured by a thermometer, which is an 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 discrepancy (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.



Closed-Loop Control Versus Open-Loop Control

Feedback Control Systems. A system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control is called a feedback control system. An example would be a room temperature control system. By measuring the actual room temperature and comparing it with the reference temperature (desired temperature), the thermostat turns the heating or cooling equipment on or off in such a way as to ensure that the room temperature remains at a comfortable level regardless of outside conditions.

Closed-Loop Control Systems. Feedback control systems are often referred to as *closed-loop control* systems. In practice, the terms feedback control and closed-loop control are used interchangeably. In a closed-loop control system the actuating error signal, which is the difference between the input signal and the feedback signal (which may be the output signal itself or a function of the output signal and its derivatives and/or integrals), is fed to the controller so as to reduce the error and bring the output of the system to a desired value. The term closed-loop control always implies the use of feedback control action in order to reduce system error.

Closed-Loop Control Versus Open-Loop Control

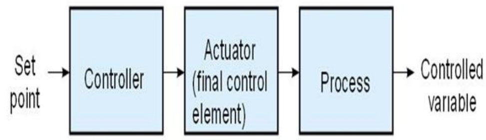
Open-Loop Control Systems. Those systems in which the output has no effect on the control action are called open-loop control systems. In other words, in an open loop control system the output is neither measured nor fed back for comparison with the input. One practical example is a washing machine. Soaking, washing, and rinsing in the washer operate on a time basis. The machine does not measure the output signal, that is, the cleanliness of the clothes.

In any open-loop control system the output is not compared with the reference input. Thus, to each reference input there corresponds a fixed operating condition; as a result, the accuracy of the system depends on calibration. In the presence of disturbances, an open-loop control system will not perform the desired task. Open-loop control can be used, in practice, only if the relationship between the input and output is known and if there are neither internal nor external disturbances. Clearly, such systems are not feedback control systems. Note that **any control system that operates on a time basis is open loop**. For instance, traffic control by means of signals operated on a time basis is another example of open-loop control.

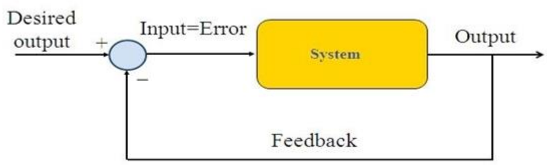
Closed-Loop Control Versus Open-Loop Control

Closed-Loop versus Open-Loop Control Systems

- Open-Loop



- Closed-Loop



Closed-Loop Control Versus Open-Loop Control

Closed-loop controllers have the following advantages over open-loop controllers:

- Disturbance rejection
- Guaranteed performance even with model uncertainties, when the model structure does not match perfectly the real process and the model parameters are not exact
- Unstable processes can be stabilized
- Reduced sensitivity to parameter variations
- Improved reference tracking performance

Design and Compensation of Control Systems

This course discusses basic aspects of the design and compensation of control systems. **Compensation** is the modification of the system dynamics to satisfy the given specifications. The approaches to control system design and compensation used in this course are the root-locus approach, and frequency-response approach.

Performance Specifications. Control systems are designed to perform specific tasks. The requirements imposed on the control system are usually spelled out as performance specifications. The specifications may be given in terms of **transient response requirements** (such as the maximum overshoot and settling time in step response) and of **steady-state requirements** (such as steady-state error in following ramp input) or may be given in **frequency-response terms**.

- Performance specifications are related to accuracy, relative stability, and speed of response.

Design and Compensation of Control Systems

System compensation. Setting the gain is the first step in adjusting the system for satisfactory performance. However gain adjustment alone is not enough.

- Good for the steady-state behavior
- Poor stability
- Additional device is called compensator

Design Procedures. Set up a mathematical model and adjust the parameters of a compensator. Use MATLAB software to conserve time.