Course of "Automatic Control Systems" 2022/23

Introduction

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⚔ In a control problem we need to design a controller that imposes the **desired behavior** to the assigned process, or **system under control**.

⚔ The desired behavior consists of imposing a specified time behavior of some variables associated with the process. These variables are usually called **variables under control** and the desired behavior is called **reference signal** or **set-point**.

⚔ The ideal aim of a control strategy is to find the control law such that

$$\textbf{variables under control = reference signal} \tag{1}$$

Satisfying equation (1) is almost impossible in real systems for different reasons….

An active control system (manual or automatic) can be logically divided in three parts:
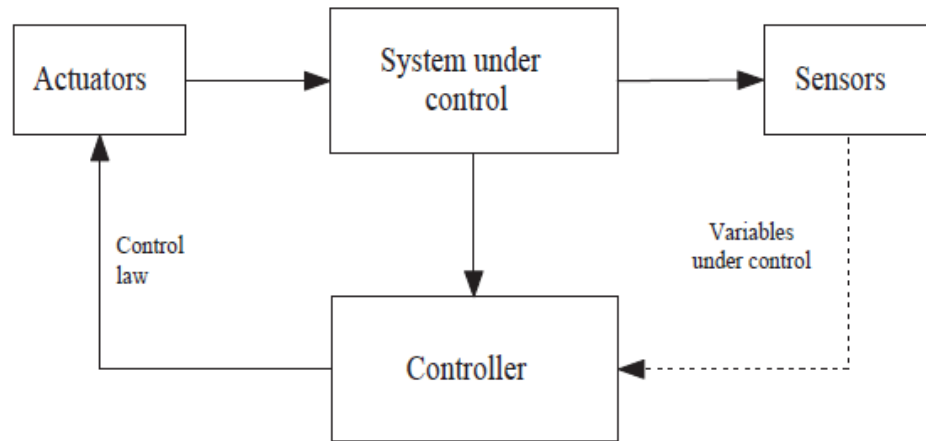
Sensors:

whose aim is to measure of the quantities of interest (related to the variables under control) in order to evaluate the behavior of the system under analysis
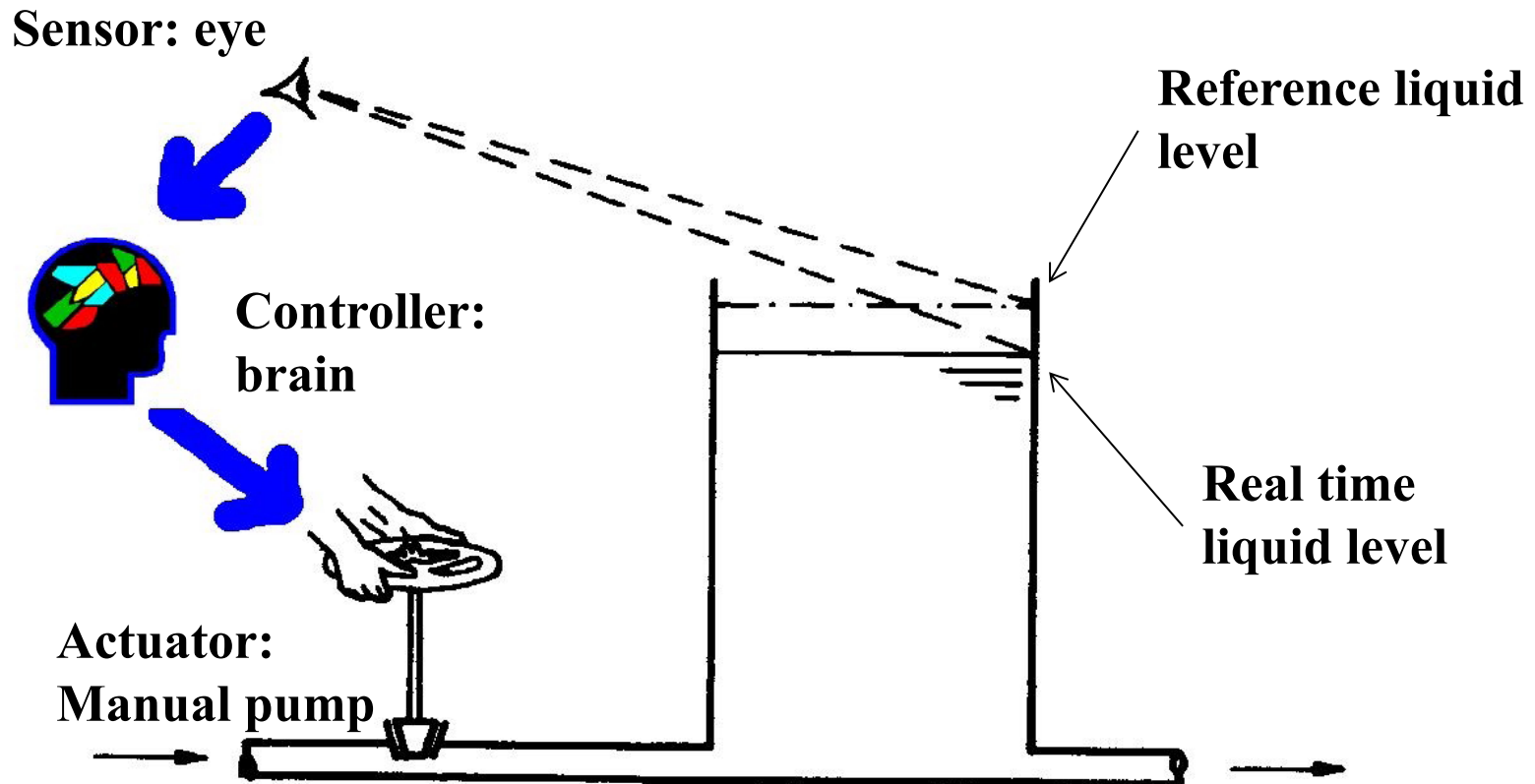
Controller:

whose aim is to impose the desired behavior to the system under control, making use of the values of the sensed variables (if available).
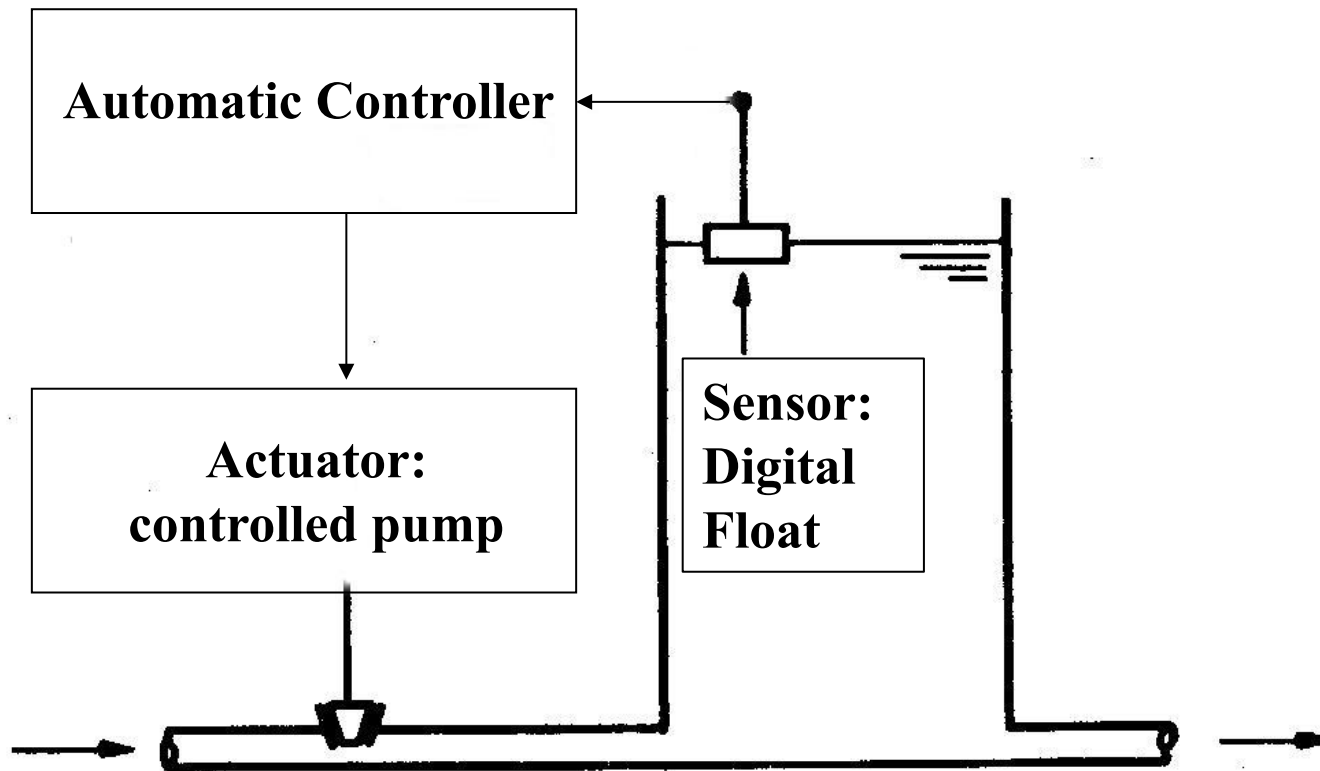
Actuators :

whose aim is to implement the computed control actions on a set of **control variables** (related but usually not coincident to the variables under control)

Sensor: eye

Reference liquid level

Controller: brain

Real time liquid level

Actuator: Manual pump

⚔ Let us assume that a vehicle must be carried from a point A to a point B along an assigned planar trajectory and with an assigned velocity.

⚔ The **control variables** are the angular position of the steer for the position and the gas pedal, the break pedal and the gear for the velocity:

⚔ The **actuator** is the transmission system

⚔ the **sensors** consist in the speed indicator for the velocity and the driver's eyes for the position.

Actuate
Gas Pedal

Sense
Vehicle Speed

Compute
Control Action
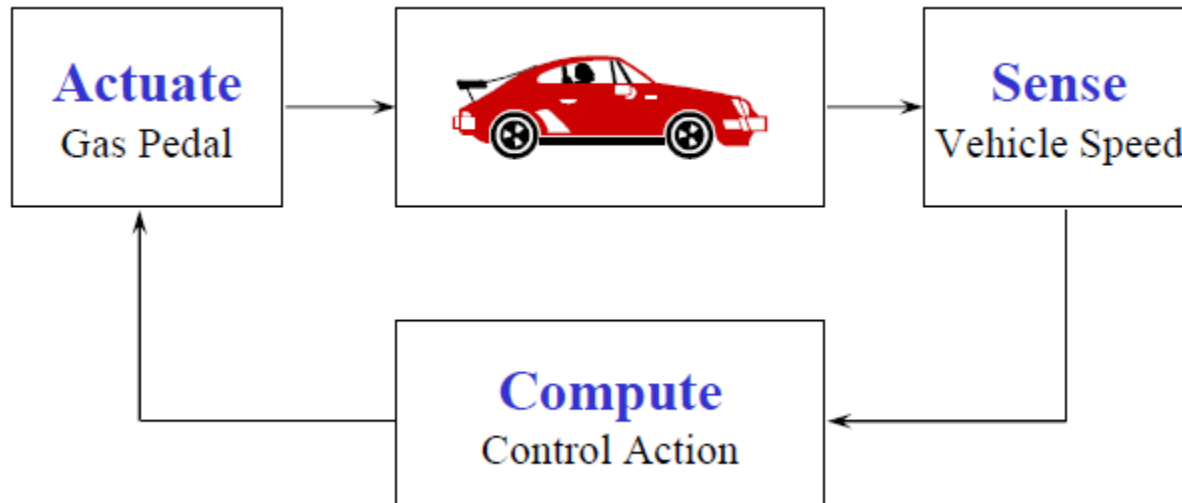
⚔ Looking at Example 1-2 it should be evident that satisfying equation (1) precisely is not possible in many real control problem.

⚔ This is due to

1. the ***dynamics of the system under control***: the control action usually refers to the set of control variables that are related to the variables under control by means of the system dynamics.

2. **the limits of the actuators**

3. the possible presence of ***uncertainties* and *disturbs*** affecting both the systems and the actuators/sensors

⚔ A ***disturb*** is external input of the systems that can not be controlled.

⚔ The disturbs usually influence the value of the variables under control and so the ***aim of the controller is to neutralize their effect***.

⚔ However, the disturbs are usually time variant and uncertain. In the control design it is assumed to know the ***nominal value*** and some information about the type and the intensity of the disturbs.

⚔ The **uncertainties** in a real system are in general due both to the sensor/actuator blocks (*measurement uncertainties*) and to the model of the system.

⚔ The first cause of model uncertainties is related to the necessity to consider **simplified version of complex system** for the controller design.

⚔ An other cause of uncertainty is the presence of **unknown parameters in the model**.

In case of uncertainties and disturbs, robust control strategies are used to guarantee a limited loose of performance of the controller.

↡ The control systems are usually classified depending on the information they use to evaluate the control law.

↡ In an **open loop control strategy**, the controller inputs are the set point at each instant of time and, in some cases, information concerning the disturbs.

↡ These information, together with the knowledge of the mathematical model of the system, allows the control system to elaborate the control law.
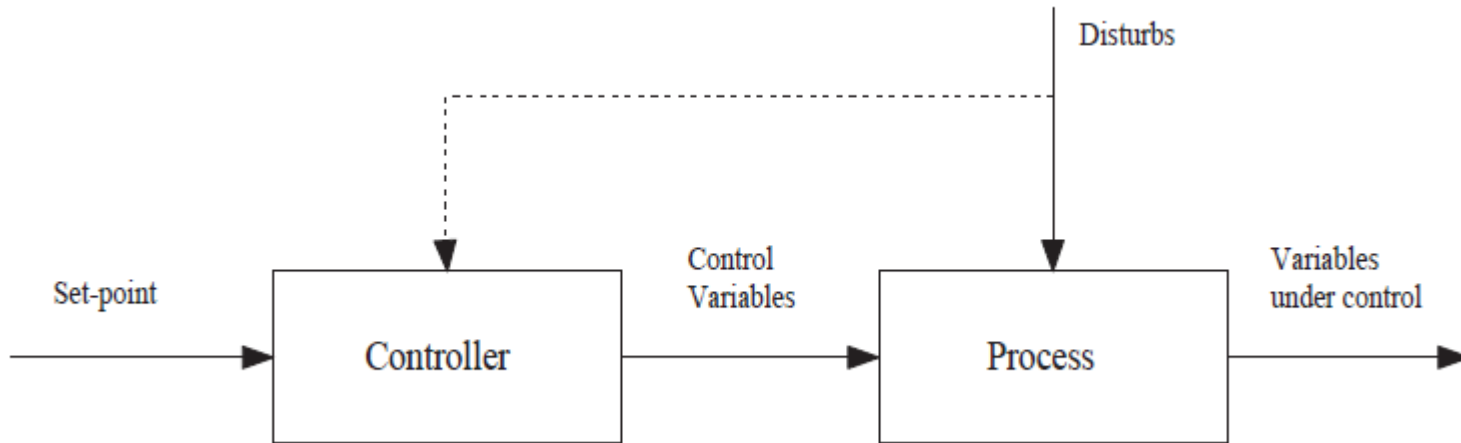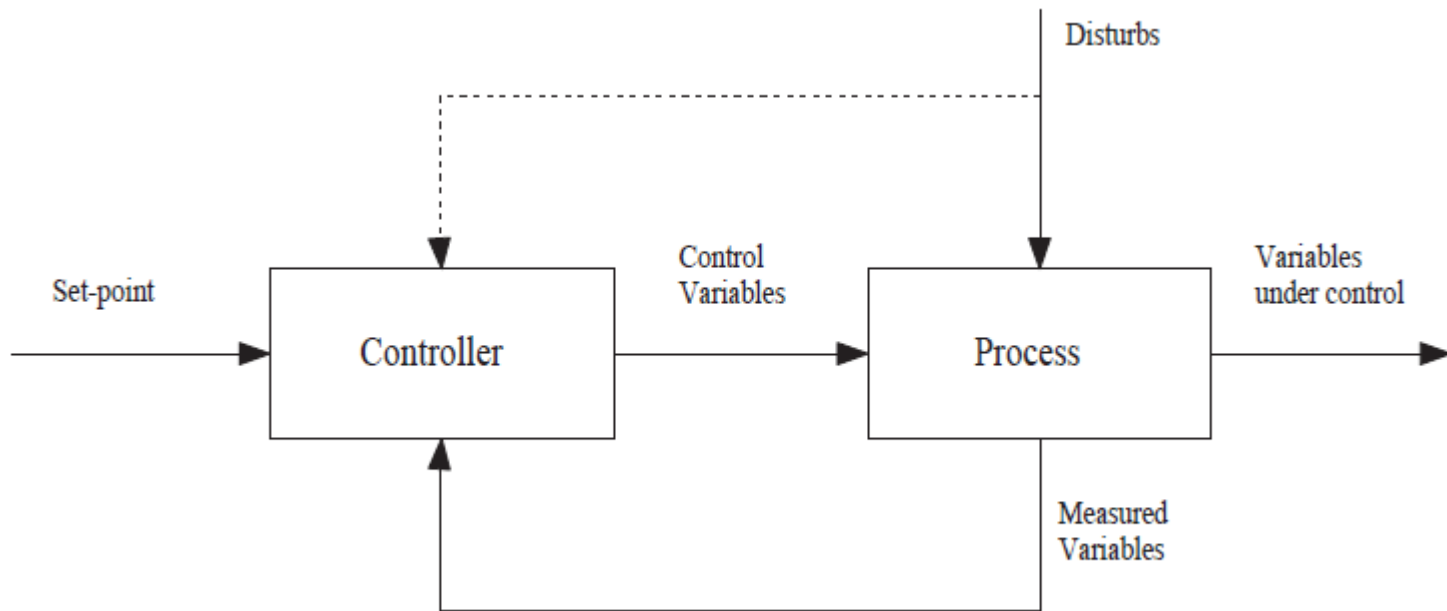

Open loop control strategy

⚔ If the knowledge of the system is precise, there aren't any uncertain parameters and the disturbs assume their nominal value an open loop controller will work correctly. ***However an open loop control strategy is not robust.***

⚔ In a ***closed loop control strategy ,*** the controller uses the real time values of the sensed variables in order to define a robust control law.

Closed loop control strategy

⚜ The **mathematical model** of the system describes its evolution starting from an initial condition. A mathematical model of a system is composed by

1. **State variables** $x = [\ x_1\ \ x_2\ ...\ x_n\ ]^T \in R^n$:set of variables describing the state of the system in a given instant of time

2. **Input variables** $u = [\ u_1\ \ u_2\ ...\ u_m\ ]^T \in R^m$: set of variables describing the interaction of the system with the environmental.

3. **Dynamic equations:** set of differential equation describing how the system evolves starting from an initial state x_0 at the time t_0 under the input u

$$\dot{x}(t) = f(x(t), u(t), t) \qquad x(t\_0) = x\_0$$

4. **Output variables** $y = [\ y_1\ \ y_2\ ...\ y_p\ ]^T \in R^p$: set of measured variables and variables under control related to the state variables of the system. The relation of the outputs with the state of the system can be expressed as

$$y(t) = g(x(t), u(t), t)$$

♤ The first part of the course will focus on the **_analysis in the time and frequency domains of linear time invariant (LTI) systems_** in the form

$$\dot{x}(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t) + Du(t)$$

with $A \in R^{n \times n}$, $B \in R^{n \times m}$, $C \in R^{p \times n}$, $D \in R^{p \times m}$, where $x(t)$ is the state vector, $u(t)$ is the input vector and $y(t)$ is the output vector of the system.

♙ Then, the course will tackle the ***closed loop control of LTI systems.***