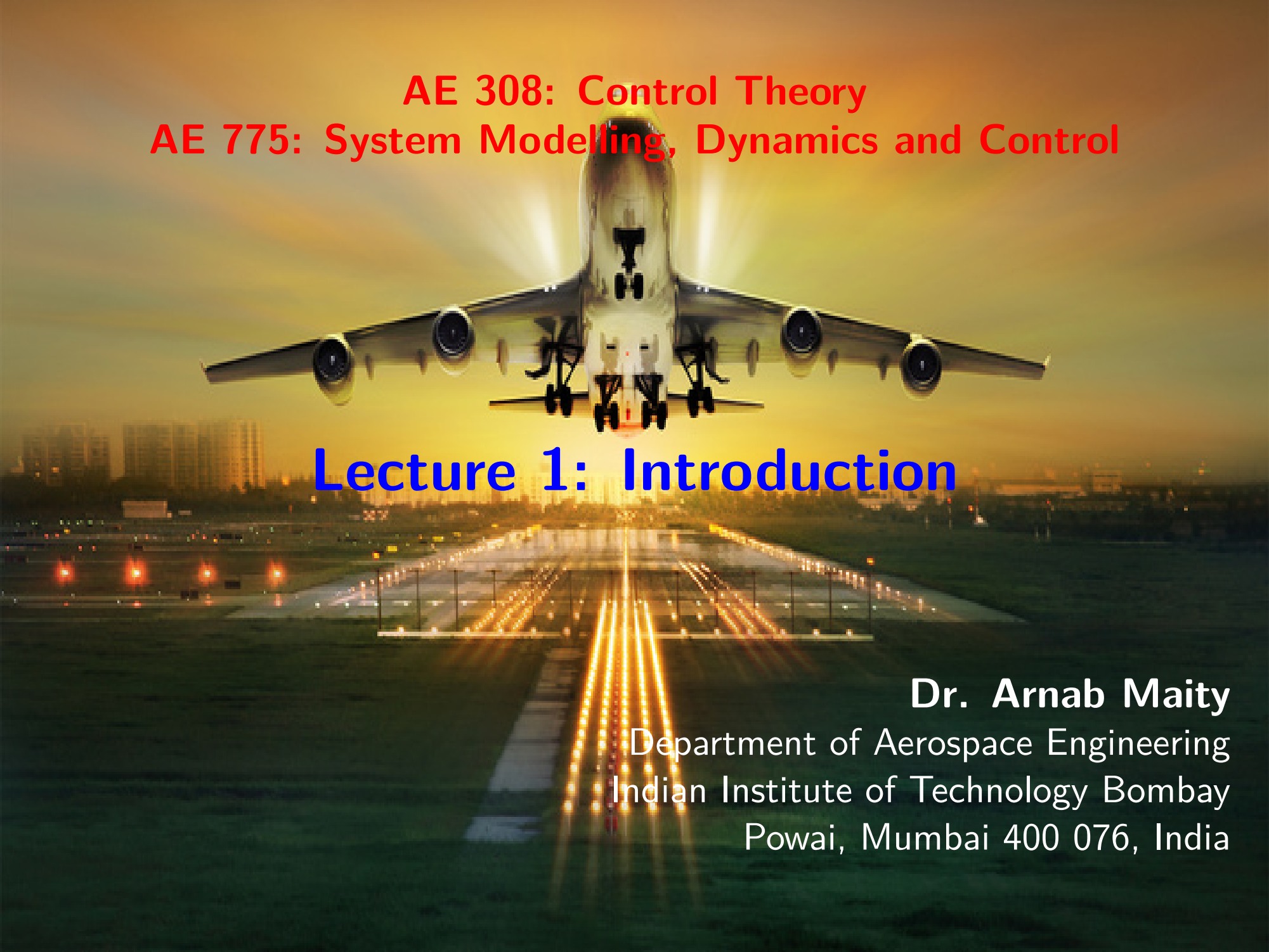

AE 308: Control Theory
AE 775: System Modelling, Dynamics and Control

Lecture 1: Introduction

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Grading Policy

	Percentage	Tentative Date
Attendance	10%	Biometric
Quiz-1	7.5%	22 August, 2022
Quiz-2	7.5%	13 October, 2022
Project	20%	TBA
Assignments	15%	TBA
Mid Sem	15%	As per Academic Schedule
End Sem	25%	As per Academic Schedule

Note: This is tentative. It may be revised dependent on situations. If there is any revision, it will be notified to you.

Tutorial Schedule

	Tentative Date
Tutorial 1	08 August 2022
Tutorial 2	29 August 2022
Tutorial 3	12 September 2022
Tutorial 4	10 October 2022
Tutorial 5	07 November 2022

Your Expectations

Your Expectations?

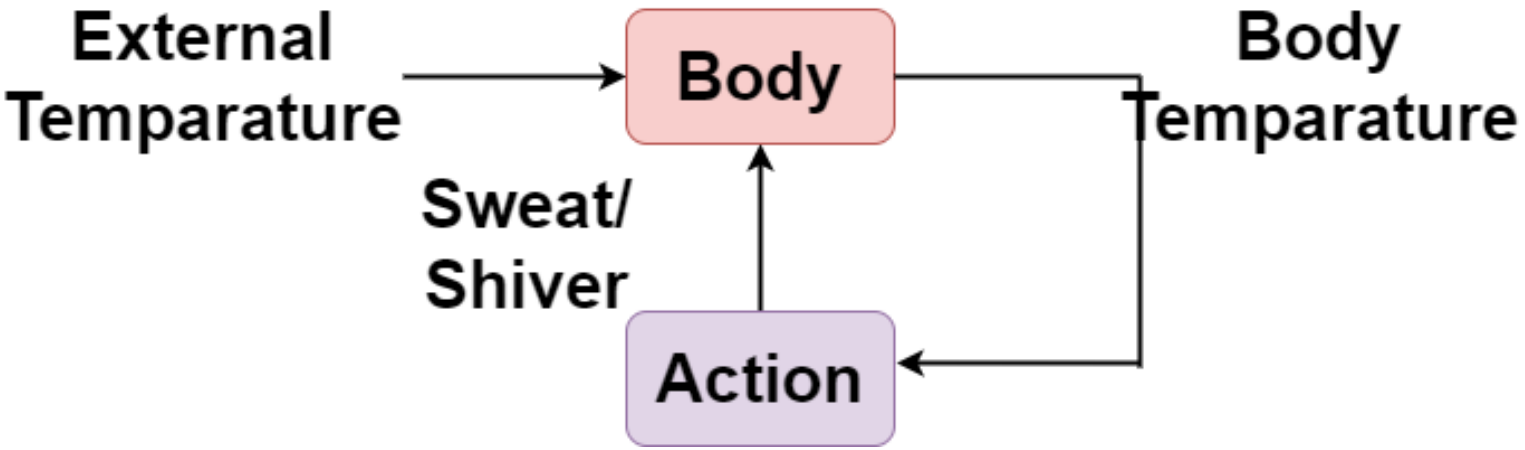
Motivation

What is control system?

Why a control system is required?

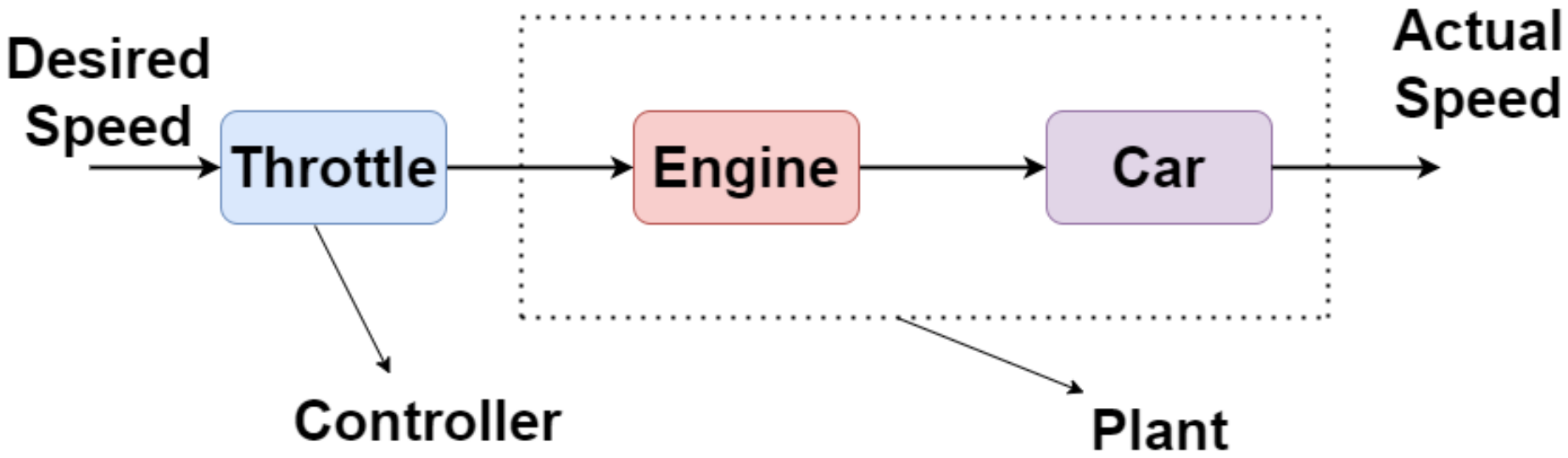
Motivation

Natural control system within human body:



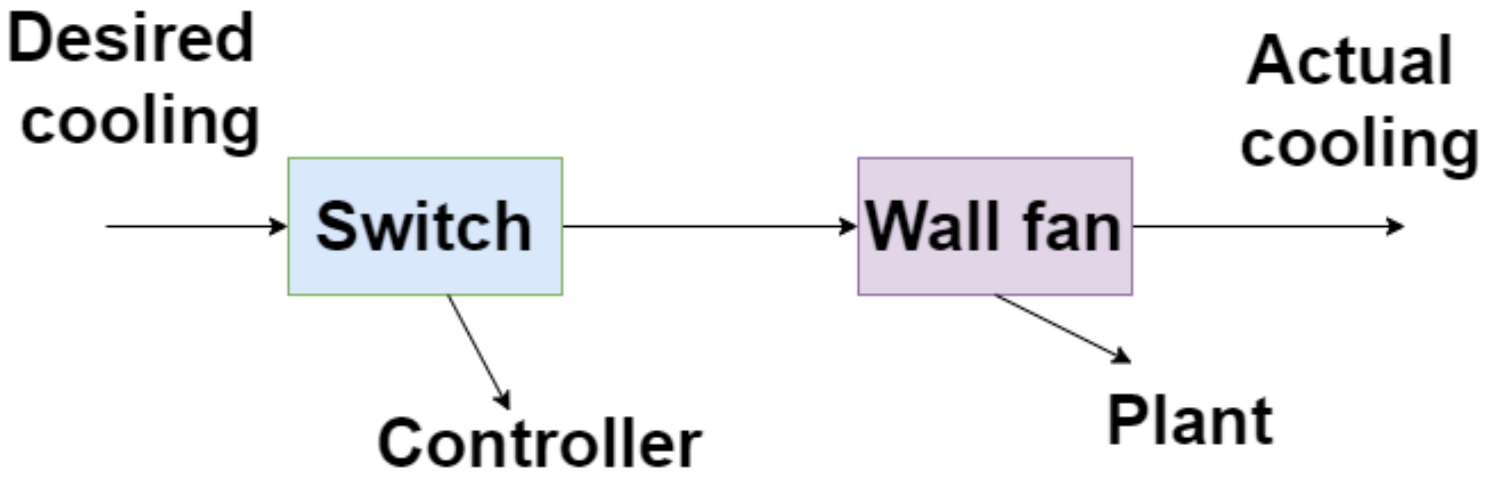
Motivation - Common Examples

Car speed:



Motivation - Common Examples

Room fan:



Motivation - Complex Examples

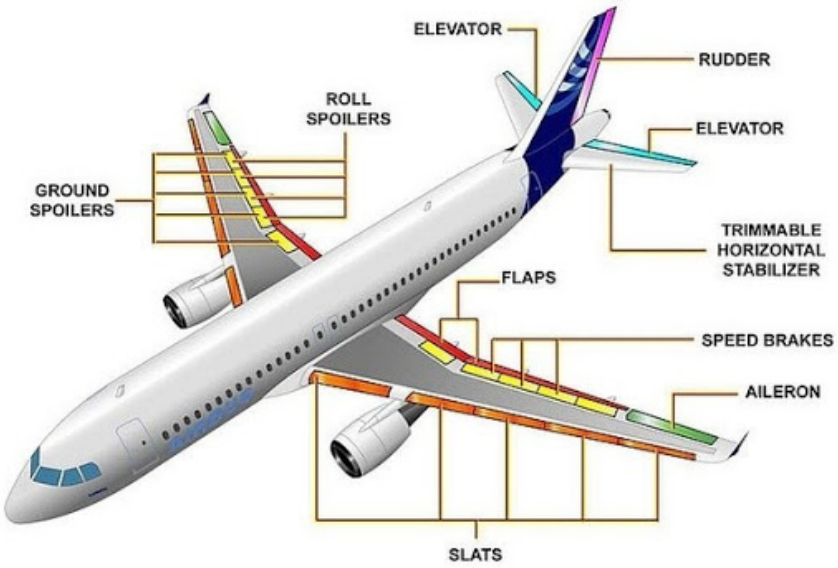


Figure: Flight control system

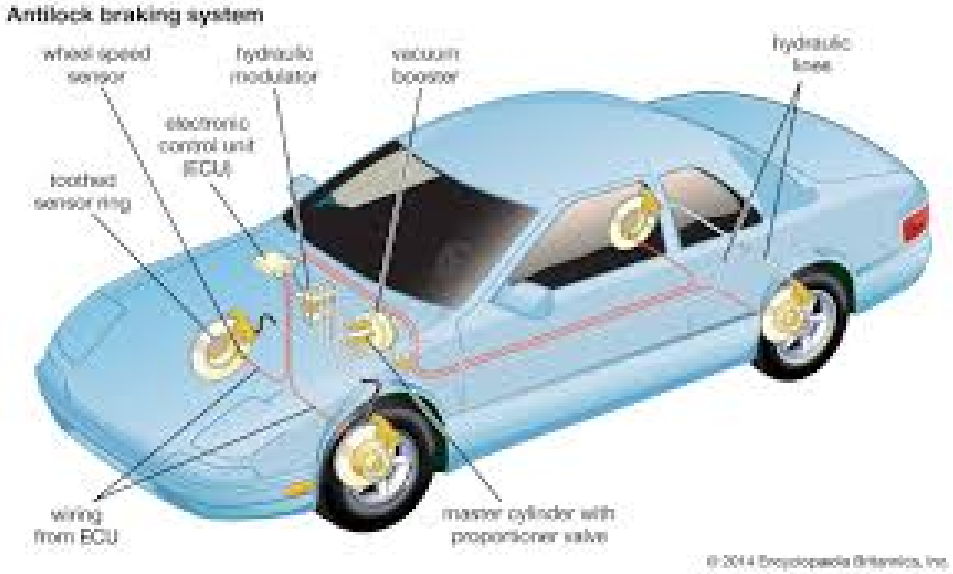


Figure: Anti-lock braking system

Motivation - Basic Control Questions

As a control engineer, what should I know and what should I ask?

Motivation - Basic Control Questions

- What are the system outputs that have to be controlled?
- What information is necessary?
  - What the system needs to do?
  - How well is the system doing?
  - What the control action keeps to maintain?

Motivation

Why control systems

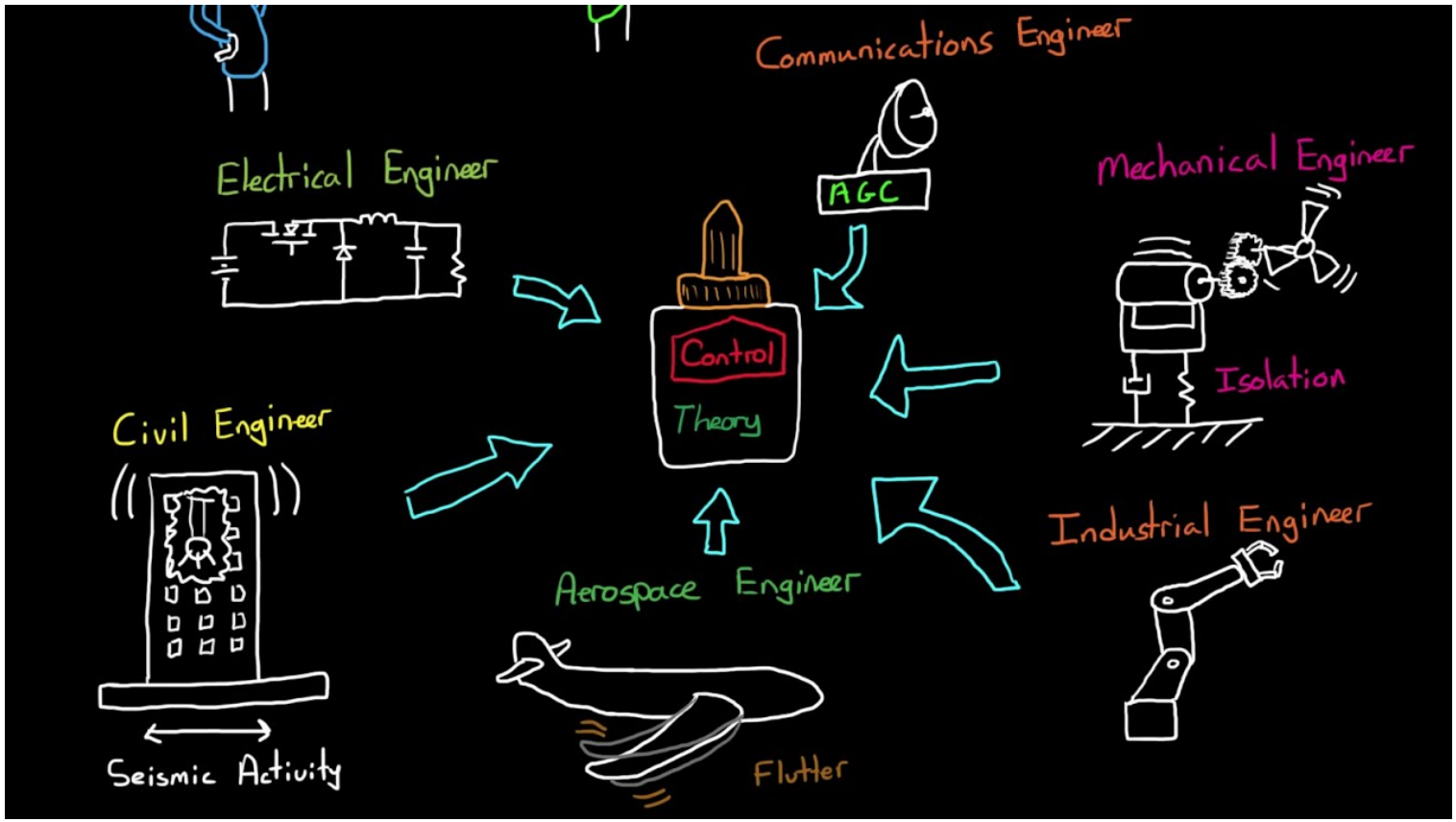
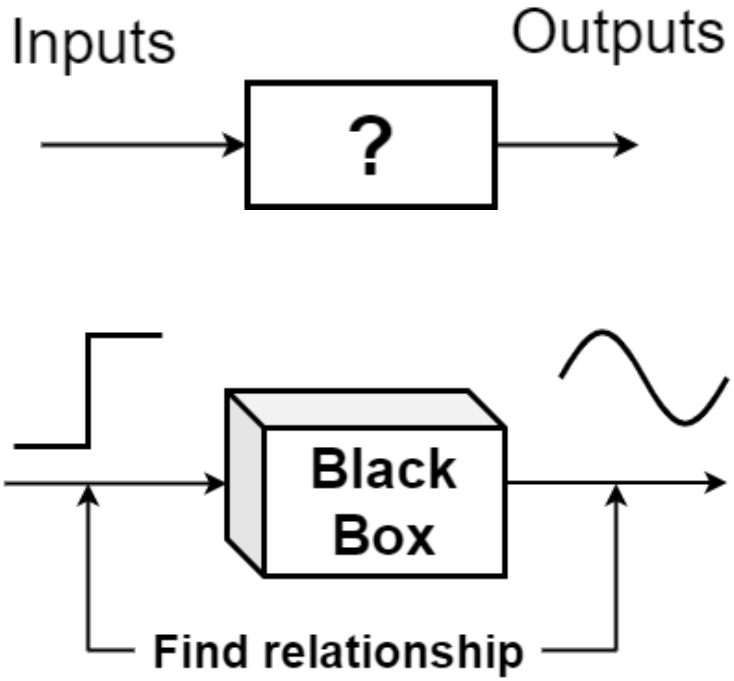


Figure: *Source - "The Fundamentals of Control Theory" by B. Douglas*

Big Picture



- The box represents the system.
- The inputs drive the system and generate the outputs.
- At any given point of time, the problem statement is based on the following:
  - System identification problem
  - Simulation problem
  - Control problem

Big Picture - System Identification Problem

System identification problem

- As a practising engineer, a model of the system is not always readily available.
- The process of determining a mathematical model is called **system identification**.
- Relevant questions regarding the system identification are
  - How to model the system that we are trying to control?
  - What is relevant dynamics for the system?
  - What are mathematical equations that convert known inputs to measured outputs?
- These can be answered in two ways as the following.
- The first is referred as **black box method**. Imagine that you do not know anything about the system.
- One can subject the material in box to various inputs and measured outputs, and infer what is in the box based on the relationship between inputs and outputs.

Big Picture - System Identification Problem

- The second way is to perform through **white box method**.
- Imagine you know all the components inside the box.
- This is exactly similar to the Newton's method or determining equations of motion based on energy in the system.

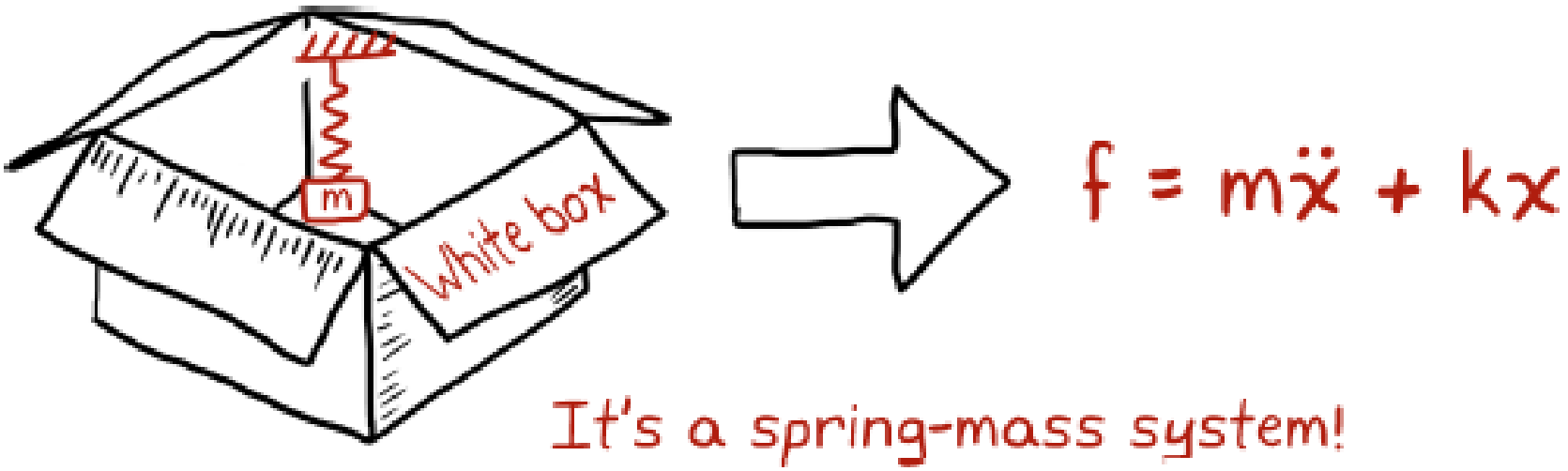
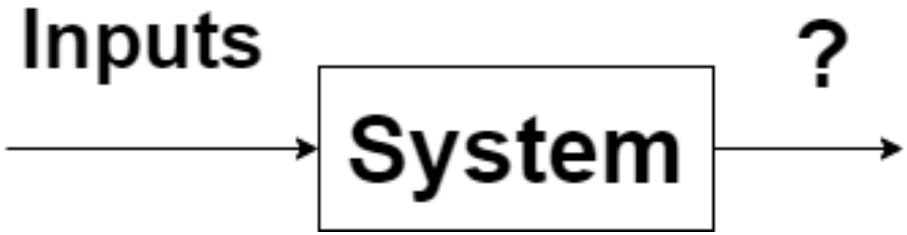


Figure: *Source - "The Fundamentals of Control Theory" by B. Douglas*

Big Picture - Simulation Problem

Simulation problem

- The process of predicting the change in outputs for a given set of inputs and the mathematical model is known as simulation problem.
- The simulation test is required, if one is interested to know the following:
  - Does the system model match the test data?
  - Will the system work in all operating conditions?
  - How does the system behave, if it is driven by potentially destructive commands?

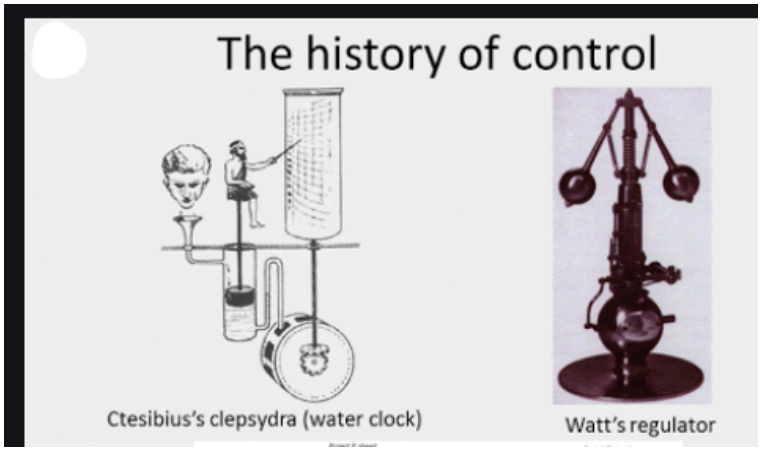


Big Picture - Control Problem

Control problem

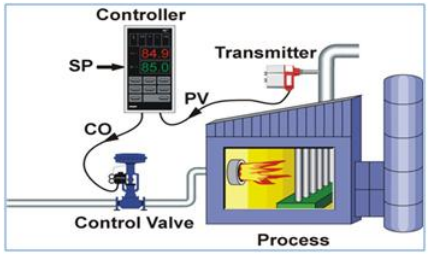
- If we know the system as well as how we want the system output to behave, then we can determine the appropriate input using the control theory.
- The process of determining the appropriate input, that will produce the desired output, is control problem.
- Control theory helps to solve this type of problems.
- Without control theory, a designer can obtain control input using trail and error method, which may be a tedious job for practical systems.

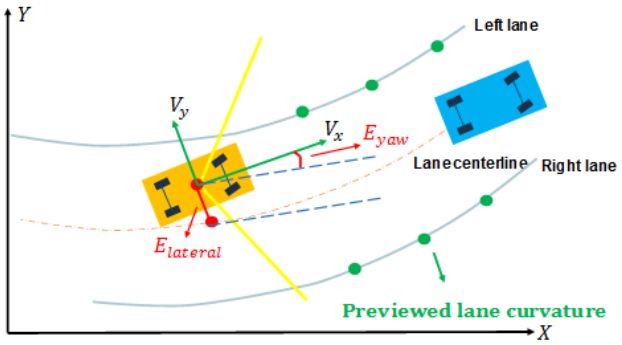
History of Control Systems

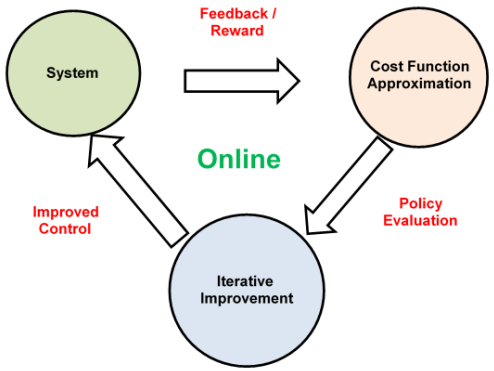


- In **18th Century**, James Watt's centrifugal fly ball governor for the speed control of steam engine.
- In **1920s**, Minorsky worked on automatic controller for steering ship and showed that its stability is influenced by governing differential equations.
- Nyquist developed a simple procedure for determining the stability of closed-loop system based on open-loop response to sinusoidal input.

History of Control Systems

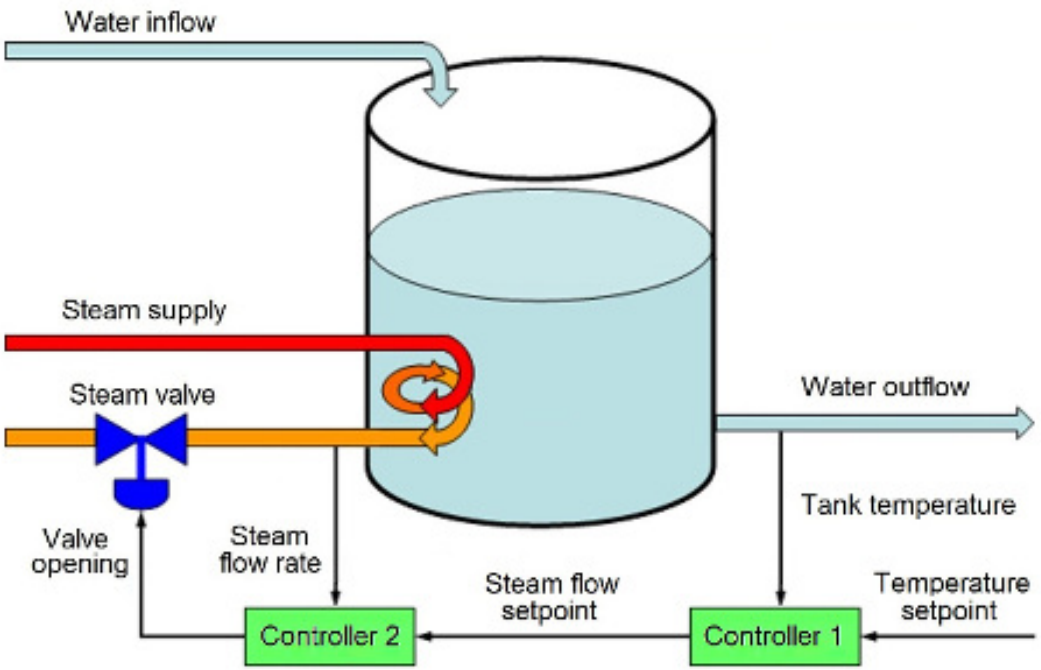






- Ziegler-Nicholos suggested rules to tune PID parameters.
- State space methods, such as optimal control theory and adaptive control theory, have been explored.
- Learning based control was started in **1980s**.

Temperature Controller

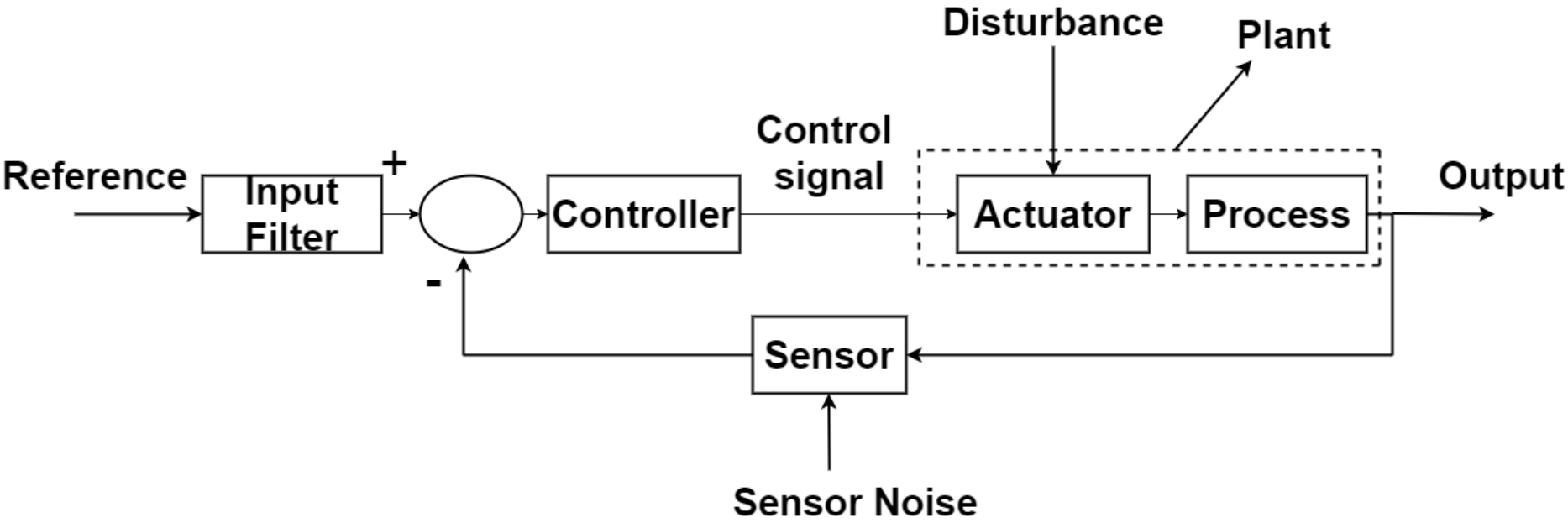


- The second controller takes the responsibility for manipulating the valve opening from the sensor (monitoring the steam flow rate).
- First controller tells the second controller how much heat it wants in terms of steam flow rate.
- Second controller manipulates the valve opening until desired steam flow is achieved.

Temperature Controller

- If the rate turns out to be insufficient to produce desired temperature, first controller can demand for higher flow rate, thereby inducing second controller to provide more stream and heat (or vice versa).
- Set point: Temperature desired for water tank.
- Primary Controller : Measures water temperature in the task and asks the secondary controller to generate more/ less heat.
- Actuator : Steam flow valve.
- Primary Process : Water in the tank.
- Primary Process Variable : Tank water temperature.
- Secondary Process Variable : Steam flow rate.

Feedback Control

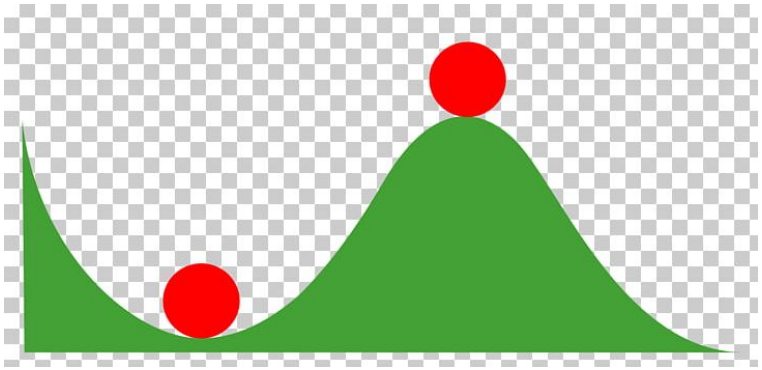


- The central component of this feedback system is the **process** whose output has to be controlled.
- The **actuator** is a device that can influence the controlled variable of process.

Feedback Control

- The combination of process and actuator is called **plant**.
- Component that computes the desired control signal is **controller**.

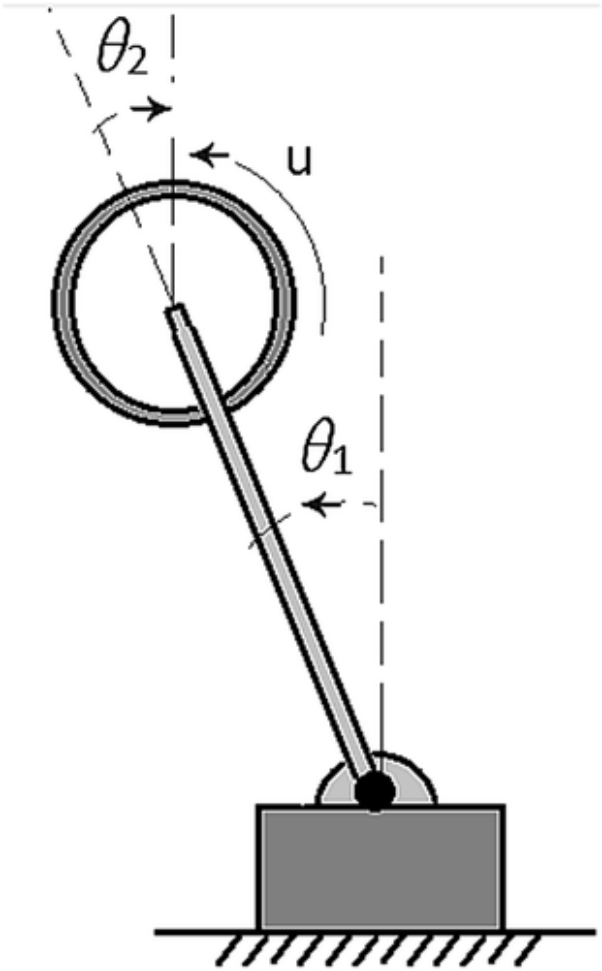
Feedback system fundamentals: Stability



- What happens, if you disturb these two balls?
- Will the stability theory answer the above question?

Feedback Control

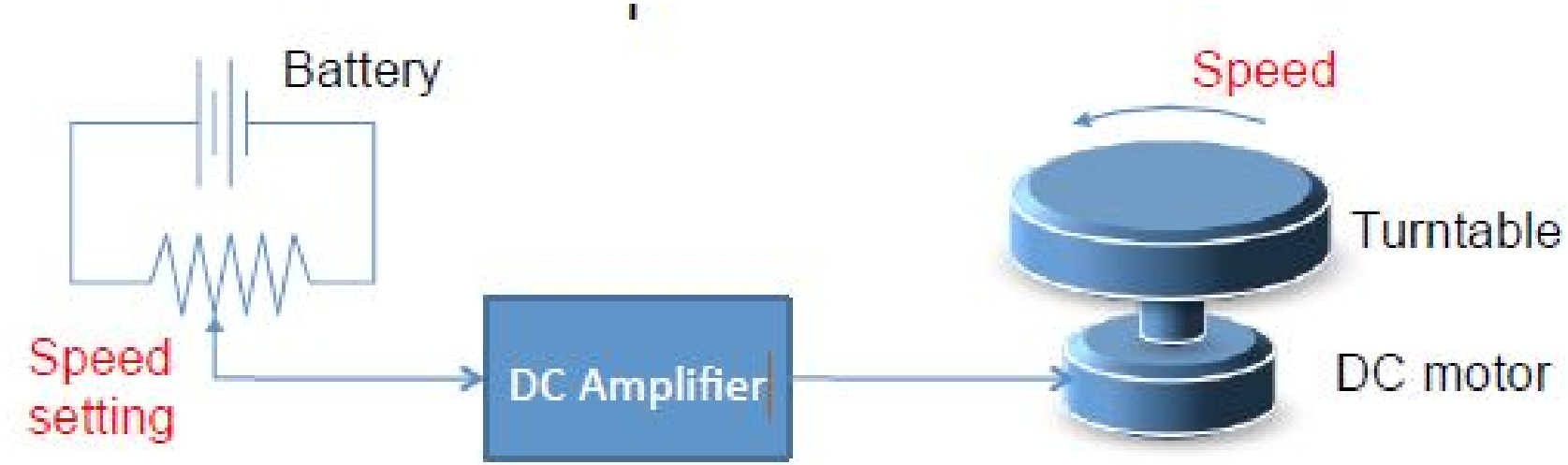
Feedback system fundamentals: Disturbance rejection

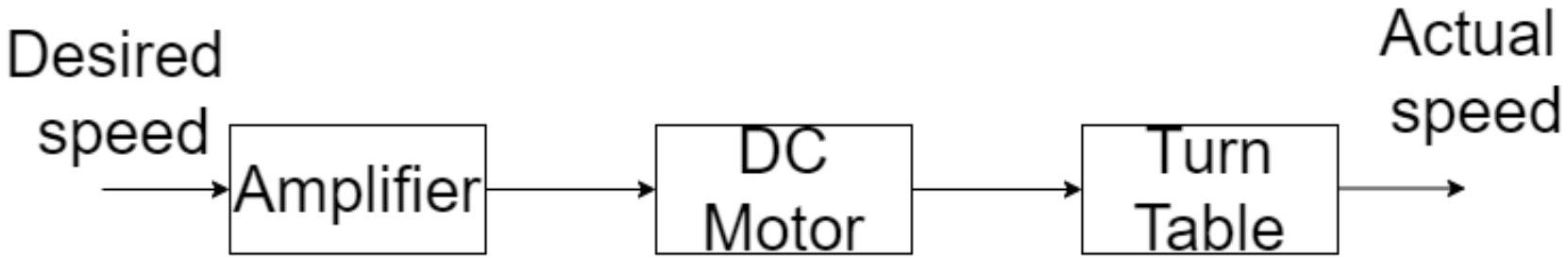


- How to achieve set point tracking in presence of external disturbances?

Open-loop and Closed-loop Control

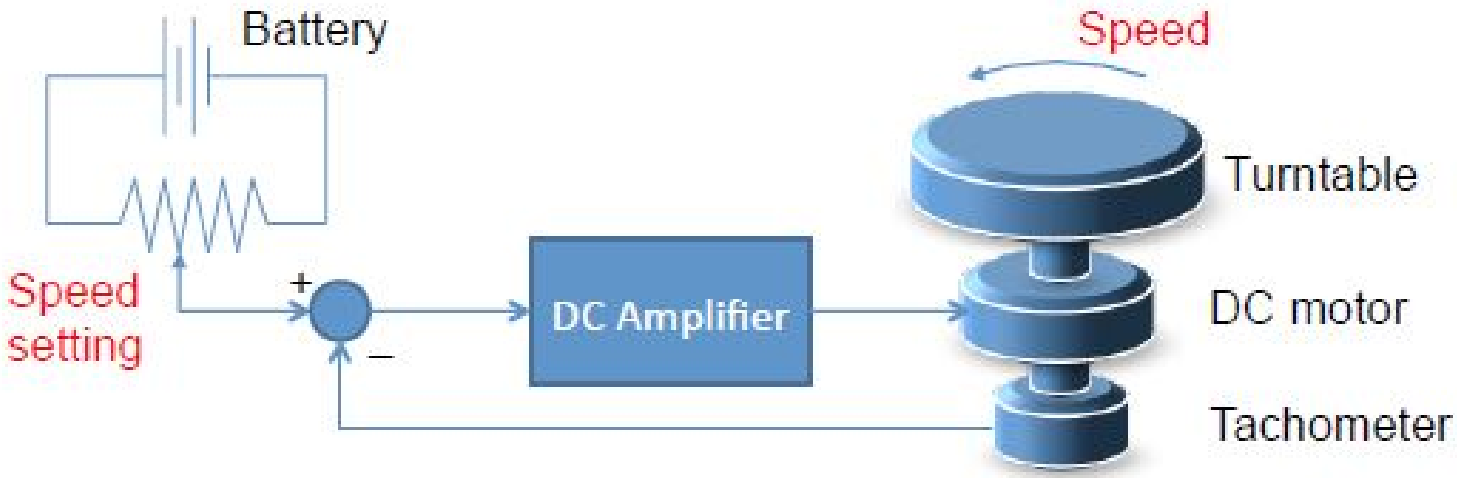
Open loop- *Turntable*

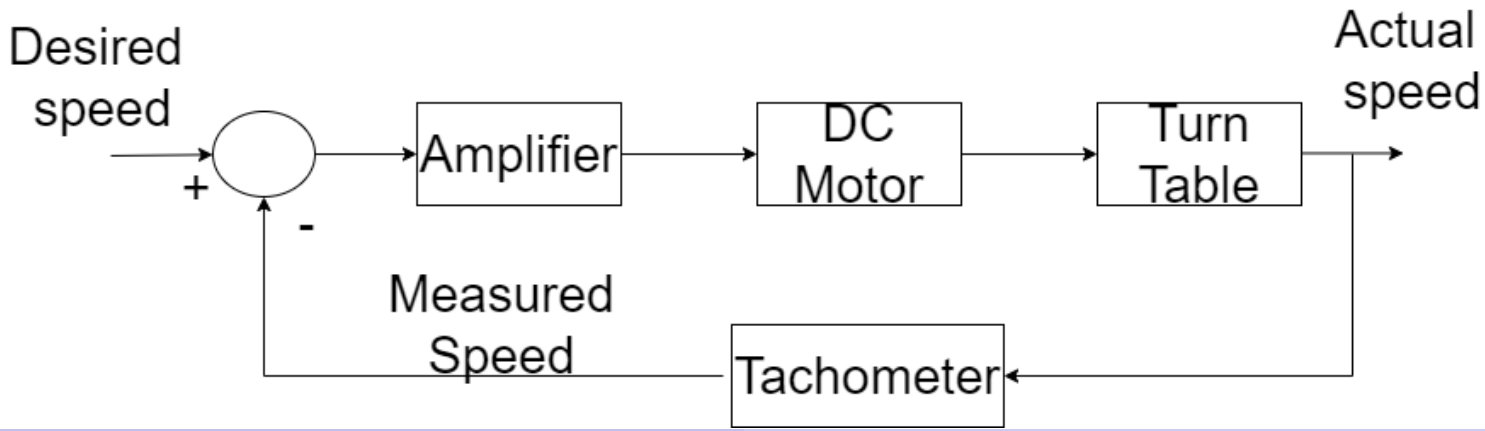




Open-loop and Closed-loop Control

Closed loop-*Turntable*





Open-loop and Closed-loop Control

Feedback control system: A system that maintains a relationship between output and reference input by comparing them and using the difference as means of control is called 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.

Open-loop and Closed-loop Control

Open-loop control systems: Those systems in which output has no effect on control action are called open-loop control sytem.

- In open-loop system, the output is not compared with the reference input.
- In presence of disturbances, an open-loop system will not perform the desired task.

Closed-loop control systems: In practice, the terms feedback control system and closed-loop control are used interchangeably.

- In closed-loop system, the actuating error signal, which is difference between input and feedback signal, is fed to controller to reduce the error and bring the output of system to the desired value.

Open-loop Control and Closed-loop Control

- An advantage of closed-loop system is that it is not so sensitive to external disturbances and internal variations in the system parameters, as it uses feedback mechanism.
- In terms of stability, the open-loop control system is easier to build, but its stability is a major concern. On the other hand, the stability of the in closed-loop control system is not a major issue as long as it is designed properly.
- It can be noted that, for systems in which inputs are known ahead of time and there are no disturbances, open-loop control system can be used.
- Closed-loop control systems have an advantage, when unpredictable components are present in the system.

Structure Chart of Control Theory

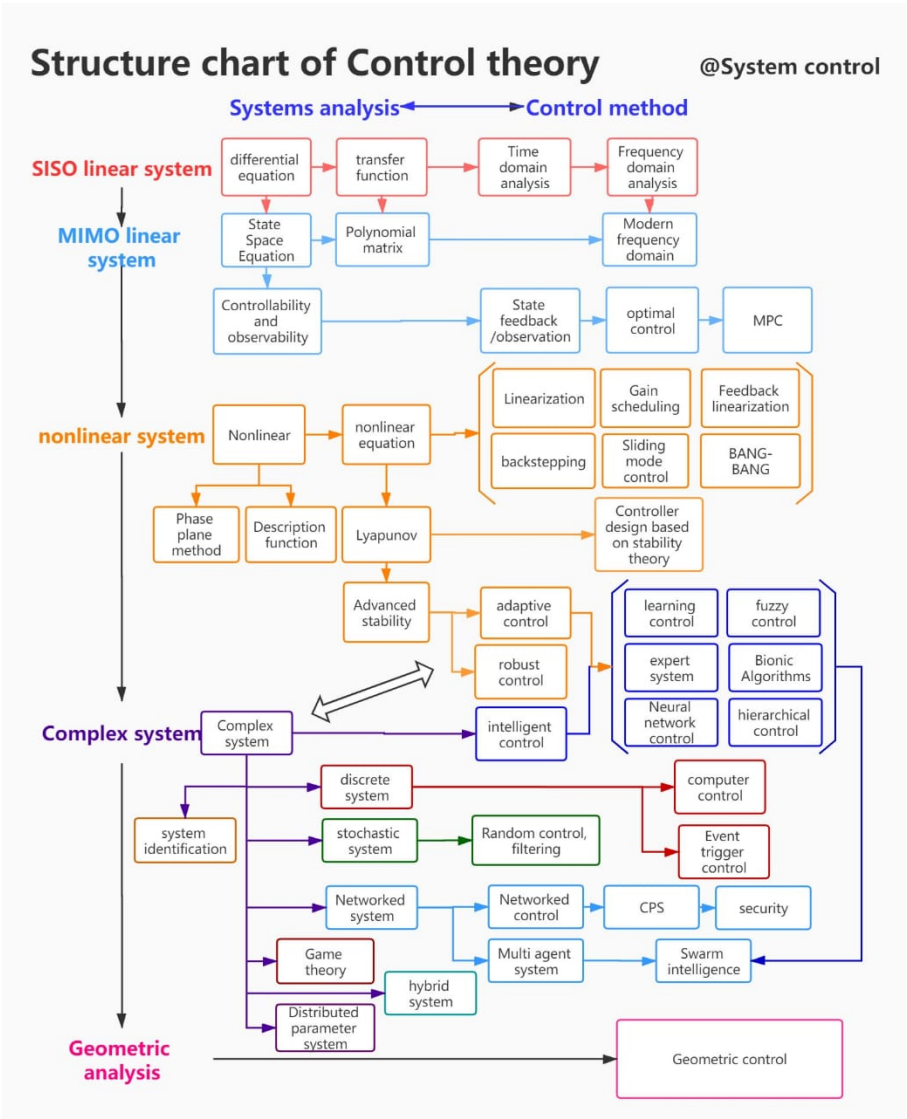


Figure: *Source - @System control*

Map of Control Theory

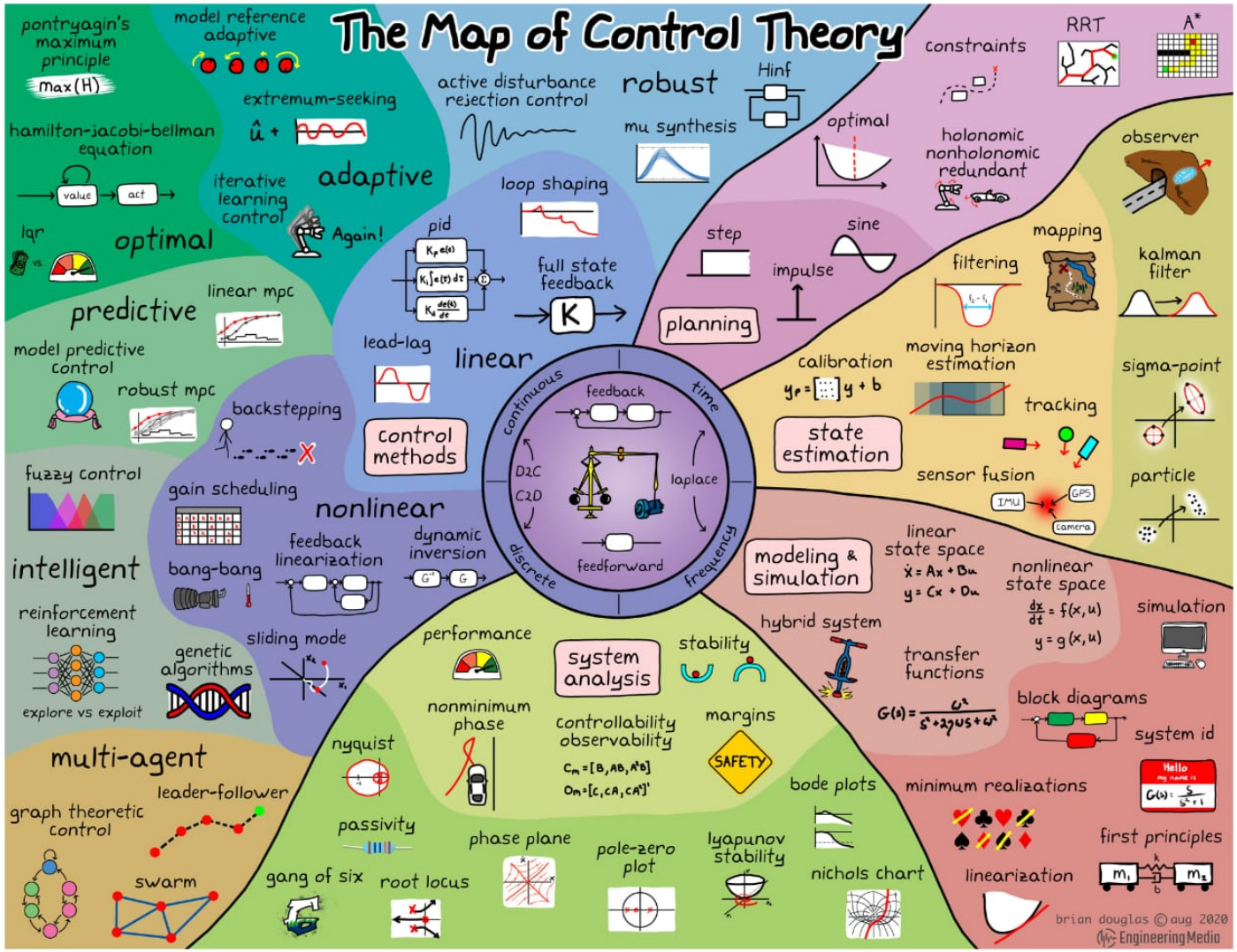


Figure: *Source - https://engineeringmedia.com/*

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