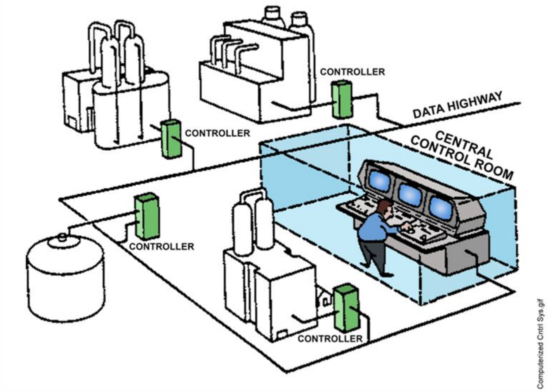
Smart Throttle Control

Introduction to Control Theory
(1)

What's a Plant

Mathematical Model of an environment we would like to control
(Input-> Output system for our use case)



Examples of a plant:

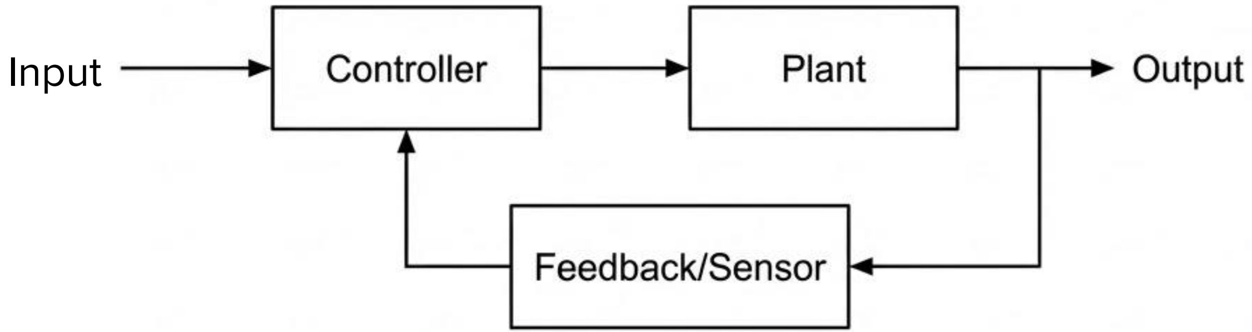
- Power plant
- Motors
- HVAC systems

$$\frac{Y(s)}{F(s)} = \frac{1}{Ms^2 + bs + k}$$

Control System

A system that manages, commands, directs or regulates the behaviour of a plant using control loops to achieve a desired result

Goal - Match actual output to the desired output
Key components - Controller, Plant, Sensor, Feedback



Laplace Transform

Transforms big differential equations into simple algebraic forms

Time Domain: Differential Equation
(Complex Plant Model)

$$\frac{d^3y(t)}{dt^3} + 5\cdot\frac{d^2y(t)}{dt^2} + 8\cdot\frac{dy(t)}{dt} + 4\cdot y(t) = 2\cdot\frac{du(t)}{dt} + 3\cdot u(t)$$

Describes system behavior with derivatives; difficult to solve directly.

$$L\{f(t)\} = \int_0^\infty f(t)e^{-st}dt$$

$$L\{f(t)\} = \int_0^\infty f(t)e^{-st}$$

Laplace Transform (L)

s-Domain: Algebraic Equation
(Simpler Transfer Function)

$$H(s) = \frac{Y(s)}{U(s)} = \frac{2s+3}{s^3+5s^2+8s+4}$$

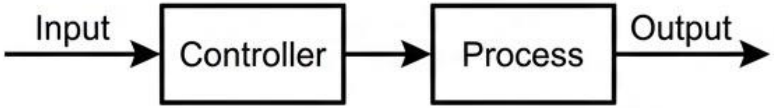
Transfer Function!!!

Transforms into an algebraic equation; simpler for analysis and design.

Types of Transfer Function

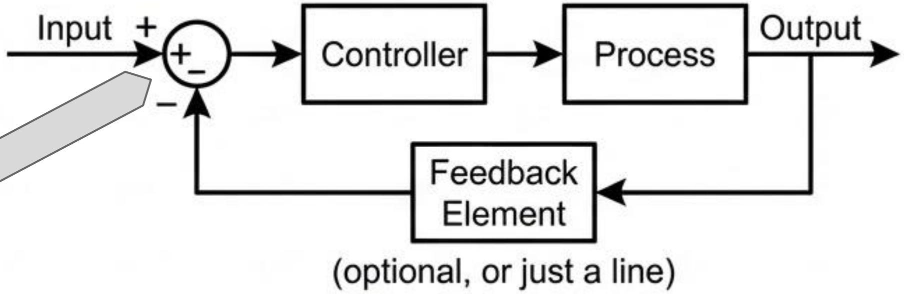
Open Loop

System where output has no effect on the control action. No feedback loop.



Closed Loop

System where output is fed back and compared with input to adjust control action. Uses feedback.



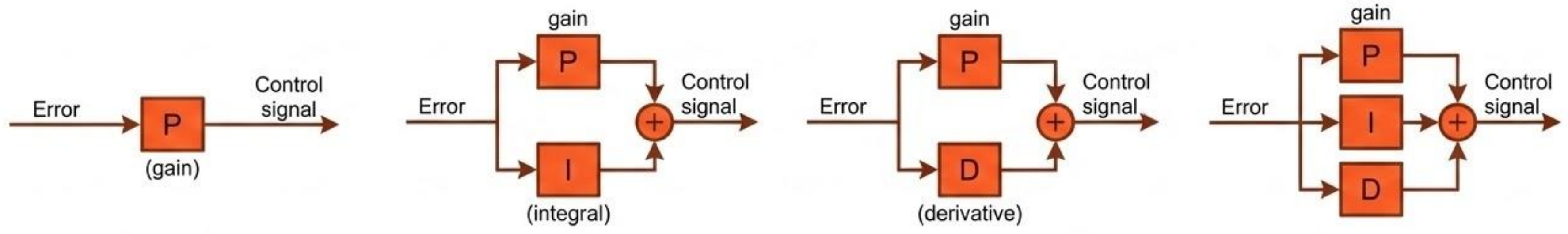
Notice a fact that error goes to the system instead of plain input making it better in many scenarios

Controller

Controller is a set of mathematical equations we put along with the plant with the objective of:

- To make system track a reference
- To reject disturbances
- To stabilize unstable systems

Some types of controllers:



Nonlinear Systems

This is where these beautiful transfer functions fail due to violation of

- Additivity (superposition)
- Homogeneity (scaling)

Laplace transform works nicely only for linear differential equations

If the system is nonlinear:

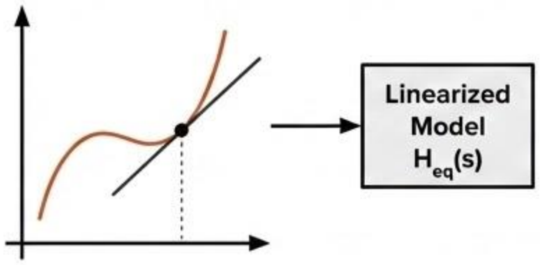
- Frequency response changes with input
- Output isn’t proportional to input

No unique transfer function can exist to describe the system’s response due to non linearity

How to handle 'em

Linearization

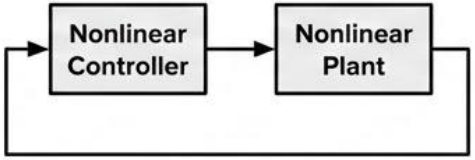
Approximate as linear around an operating point. Valid for small perturbations.



Nonlinear Control

Use advanced techniques designed for nonlinear dynamics.

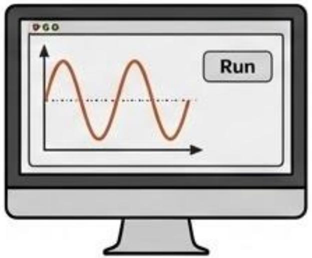
- Feedback Linearization
- Sliding Mode Control
- Lyapunov Methods



Numerical simulations

Simulate system behavior using computational tools.

- Solves differential equations directly.
- Tools: MATLAB/Simulink, Python, etc.



Manage your expectations

What to expect:

Fundamentals to behaviour

Laplace → transfer functions → controllers → system behavior

A complete story of how control is applied
You'll learn why these tools exist and how they fit together, not just pure math or pure application

A stepping stone to bigger opportunities
Once you know control fundamentals, you can confidently take projects in robotics, EVs, drones, automation, and research labs next semester

What not-to expect:

Not a hyper-specific research-paper project
We're not diving into a niche nonlinear problem or a narrow case study that you can't reuse later

Not a software heavy "black box" project
You won't just plug values into templates
You will understand what a controller does and why it works

Not a purely theoretical math course
We are not doing abstract proofs
Every concept ties to a physical interpretation & real system behavior

About the Project

This project is a guided entryway into the world of Control Systems

- broad enough to build intuition
- practical enough to be useful
- structured enough to prepare you for future projects

Final Problem statement and Mini-Projects:

The final problem statement is centered around the project itself, rather than the project being built around a predefined problem
The techniques and concepts you learn throughout this module will directly feed into both the mid-term and final problem statements

As we progress, more details about the **final project** along with the associated **mini-projects**, will be revealed in stages. Each phase is designed to build your intuition and gradually develop the skills required to tackle the complete system

Thank You !!!