Smart Throttle Control

Control Techniques-2
(4)

PID Failures

While a PID controller can technically tune most system characteristics, it faces a fundamental limitation in practical applications: **high parameter correlation.**

- **The Conflict:** The P, I, and D terms are not independent. Adjusting one to fix a specific issue (like rise time) often degrades another (like stability)
- **The Tuning Trap:** In complex real-world systems, this interdependency makes "perfect" tuning difficult (and sometimes impossible) using only a PID structure
- **The Solution:** To achieve superior performance, we move beyond PID by decoupling these requirements using **Compensators**, **Feedforward** and **MIMO strategies**

Compensators

Compensators are like fine tuning our response after the coarse adjustment is done through PID

Depending on the relative values of poles (Po) and zeros (Zo) we get:

- **Lead Compensator : (|Zo>Po|)** It increases the speed and reduces the settling time of the system
- **Lag Compensator : (|Z0<Po|)** It eliminates steady-state error with much higher precision

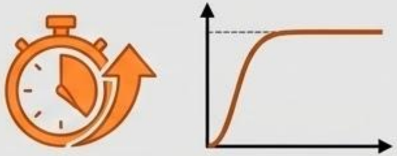
$$C(s) = K_c \frac{(s - z_0)}{(s - p_0)}$$

Lead/Lag

LEAD COMPENSATOR
(Speed & Stability)

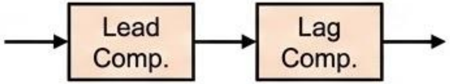
$$G_c(s) = K_c * \frac{s+z}{s+p}, \quad |z| < |p|$$

- Improves Transient Response (Faster Rise Time)
- Increases System Stability (Adds Phase Margin)
- Increases Bandwidth



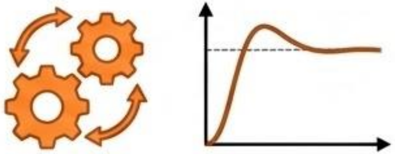
Faster Response

COMBINED LEAD-LAG
(Synergistic Optimization)



$$G_{combined}(s) \approx G_{lead}(s) * G_{lag}(s)$$

- Simultaneous Improvement of Transient & Steady-State Performance
- Balances Speed, Stability, and Accuracy
- Flexible Design for Multiple Requirements

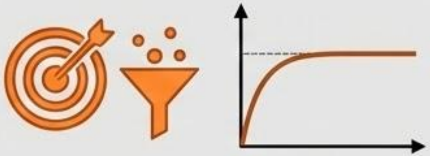


Optimal Performance

LAG COMPENSATOR
(Accuracy & Filtering)

$$G_c(s) = K_c * \frac{s+z}{s+p}, \quad |p| < |z|$$

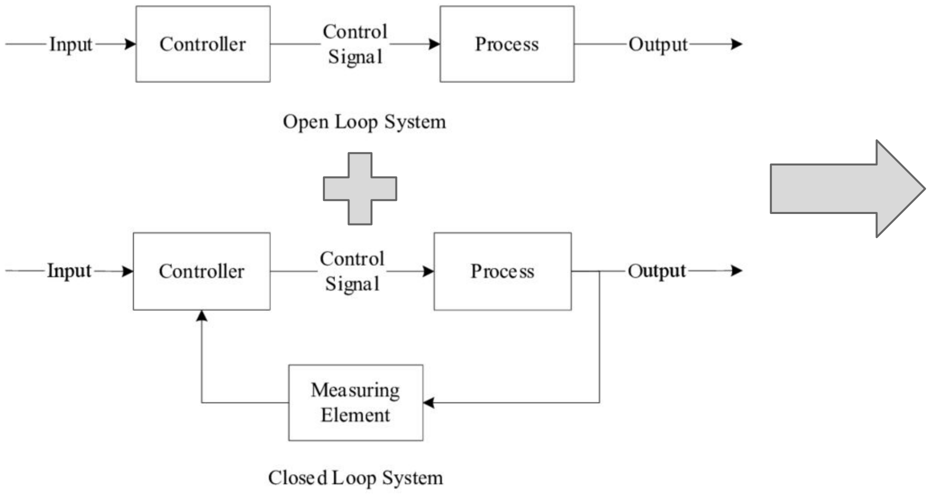
- Improves Steady-State Accuracy (Reduces Error)
- Attenuates High-Frequency Noise
- Slightly Reduces Bandwidth

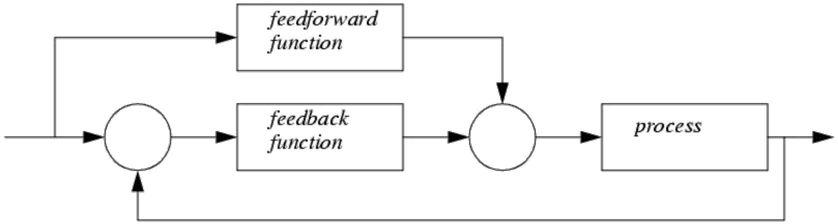


Accurate & Filtered

Feedforward Controller

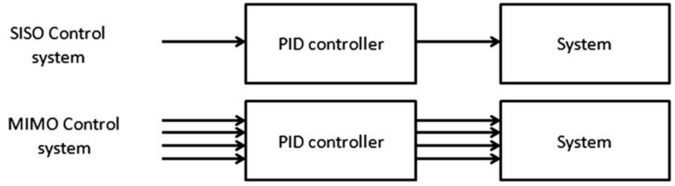
While closed loop controller are **reactive** feedforward controllers are **proactive**
Using both systems simultaneously can give us much better response in many complex systems

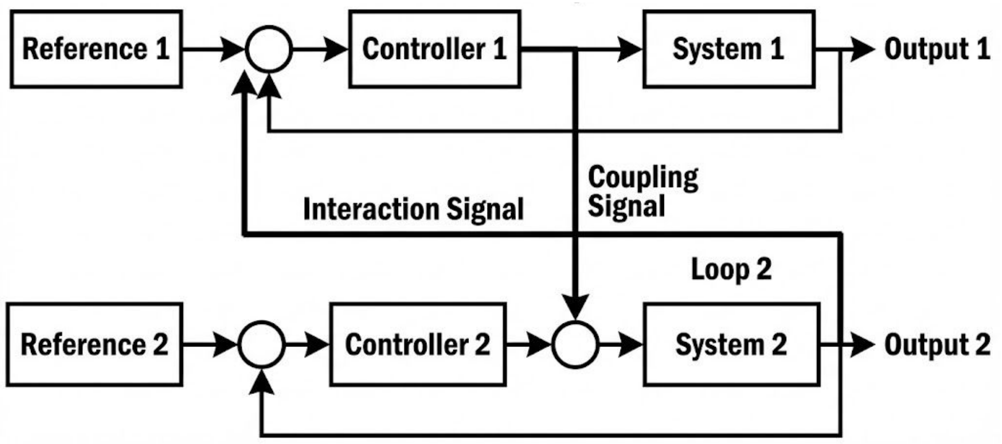




MIMO Systems

In real systems you will rarely see SISO control paths rather you see complex paths with coupling and interaction





Various Techniques:

- Decentralized Controller
- Coupling Techniques
- Model Predictive Controlling

Advanced controls !!!

Thank You !!!