Learning Objectives

• **Key Concept:** Use of feedback control to achieve high performance in an automated system.

1. Construct ordinary differential equations to approximately model the dynamics of a physical system.
2. Analyze the system response.
3. Predict the system transient response characteristics.
4. Design simple proportional-integral-derivative controllers to satisfy time-domain performance criteria.
5. Analyze the closed-loop stability via Root locus method.
6. Analyze the system property via Body plots
7. Assess the stability and robustness (gain & phase margins) of a feedback system using Nyquist theorem and plots
8. Design controllers using loop shaping and Bode plots.
9. Design and analyze controllers using state-space techniques
Example: Commercial Fly-by-Wire

Boeing 787-8 Dreamliner
- 210-250 seats
- Length=56.7m, Wingspan=60.0m
- Range < 15200km, Speed< M0.89
- First Composite Airliner
- Honeywell Flight Control Electronics

Boeing 777-200
- 301-440 seats
- Length=63.7m, Wingspan=60.9m
- Range < 9700km, Speed< M0.89
- Boeing’s 1st Fly-by-Wire Aircraft
Basic Aircraft Control

- Pitch
- Yaw
- Roll
- Wing
- Right aileron
- Horizontal stabilizer
- Vertical stabilizer
- Rudder
- Elevator
- Left aileron

Elevator → Aircraft (787) → Pitch Rate
Block Diagram: Pitch Rate Control

Desired Pitch Rate

Error

Controller

Elevator Cmd.

Actuator

Wind Gusts/ Uncertain Aerodynamics

787

Sensor

Measured Pitch Rate
The pilot pulls on the column to specify a desired pitch rate.
A gyroscope is used to measure the aircraft pitch rate.
Redundant Computers

The algorithm computations are done on multiple redundant computers for reliability.
A hydraulic actuator is used to move the elevator surface.
Questions Control Engineers Care About

- **Key Issues:** Control Engineers typically ask the following questions.

1. How to model the system dynamics?
2. What is the system response given certain reference signals?
3. What sensors/actuators to use? (Not covered in this course)
4. How to design controllers? (pole placement, loopshaping, etc)
5. Is the closed-loop system stable?
6. How fast is the closed-loop response?
7. How robust is the controller against sensor noise, actuation disturbance, and model uncertainty?
8. How to design controllers? (pole placement, loop shaping, etc)
• **Key Issues:** Control Engineers typically use the following tools.

1. Modeling tools: ODEs, transfer functions, state-space models
2. Laplace transform, inverse Laplace transform
3. Basic design tools: PID control, lead, lag, dominant pole approximation, PID pole placement
5. Performance and robustness: Bode plots
6. More general design tools: Loopshaping, state-space pole placement (state feedback and observer design)
Here are a few key words for this course:

1. Stability
2. Robustness (gain & phase margins)
3. Reference tracking
4. Noise rejection
5. Model uncertainty
6. PID, lead, lag
7. Root locus
8. Frequency domain methods: Bode/Nyquist plots, loopshaping
9. State-space methods: Controllability, observability, pole placement, state feedback, observer