1 What we have learned so far

Overview: up till now we have learned quite a few practical control design tools. In the discussion sessions we have provided some details about LQG/LTR, FSLQ, ZPET, Preview Control, derivation of closed-loop transfer functions, MATLAB coding, and Bode's Integral Formula.

A slightly more comprehensive[1] checklist is as follows:

- Design of Feedback Control System
  - Derive closed-loop transfer functions from external inputs (disturbance, measurement noise, reference) to any signal in the loop
  - The general concept of how the frequency response of the loop transfer function should look like
  - Derivation of nominal stability conditions
  - Robust stability conditions (DFC-10, DFC-12, DFC-14)
- LQG/LTR (Loop Transfer Recovery)
  - Main difference between LQG and LQG/LTR:
    - LQG is an optimal control problem. The input noise and the measurement noise physically exist in the plant.
    - LQG/LTR is a feedback controller design method. It is not an optimal control method. The plant does not have real noises. W, V, ρ, and N are design parameters we choose.
  - The use of the fictitious Kalman filter and the benefit of the target feedback loop
  - The design of the LQ cost to approximate the target loop transfer function
  - Point-wise convergence of the loop transfer function to the target feedback loop that is designed using the fictitious Kalman filter
- Frequency Shaped LQ (FSLQ) Problem
  - Performance index as a time-domain integration or a frequency-domain integration and the relationship between these two expressions
  - Design procedure: the filtered states, the enlarged system, the cost function etc
  - The optimal solution
  - Roles of Q_f, R_f and ρ
- Feedforward Tracking Control
  - Zero phase error tracking controller: cancel poles and cancellable (asymptotically stable) zeros, remove phase shift between the desired output and the output
- Preview Control (understand the idea, do not need to memorize the solution)
  - The use of future information in a length-N_p preview window
  - The use of the reference generator and how future information is built into the enlarged system
  - The transformation to a standard LQ problem
- Internal Model Principle and Repetitive Control
  - Internal model principle: including the internal model in the loop transfer function will asymptotically reject the disturbance $d(k)$
  - Internal models for basic disturbances/references
  - Repetitive controller design by pole placement or pole-zero cancellation

[1]The list may not be complete. The length of the items does not necessarily reflect the importance of the related content.

- Bode's Integral Theorem and waferbed effect (understand the idea, do not need to memorize the proof)
  - Basic concept
  - The 'waterbed' picture
  - The interpretations
- Disturbance Observer (DOB)
  - Idea of DOB: use control signal to reject disturbance by applying the inverse of the plant model
  - Derive various transfer functions in the DOB loop and analyze the stability
  - Discrete-time DOB analysis

2 Some more discussions on block-diagram analysis

Exercise: derive (quickly) the various transfer functions in the following block diagrams; analyze the closed-loop stability; construct the closed-loop system in the state space .