Advanced Process Control - Video course

COURSE OUTLINE

This course on Advanced Process Control has been designed to introduce concepts of multivariable state feedback controller synthesis using discrete time state space models. Development of control relevant dynamic models is viewed as integral part of the process of controller synthesis. Thus, the course begins with development of continuous time and discrete time linear perturbation models (state space and transfer functions) starting from mechanistic models commonly used in engineering. However, in practice, a mechanistic dynamic model may not be available for a system. In such a situation, control relevant discrete dynamic black-box models can be developed using perturbation test data. Development of output error, ARX and ARMAX models from time series data and constructing state realizations of the identified models is dealt next.

Before moving to controller synthesis, concepts of unforced and BIBO stability are introduced. In particular, stability analysis using Lyapunov functions is briefly discussed. While aim of this course is to introduce multivariable controller synthesis, multi-loop PID controllers still forms the backbone of industrial process control. Thus, tools of interaction analysis and their application to multi-loop control structure design are introduced.

Synthesis of state feedback controller is dealt in two parts. To begin with, state estimation using discrete time state space models is introduced with particular emphasis on Kalman filtering. Development of linear quadratic optimal control (LQOC) and, its popular industrial variant, model predictive control (MPC) are introduced next. In particular, emphasis is given on methods to achieve offset free control in the face model plant mismatch and unmeasured disturbances.

At the end of this course, a student is expected to have sufficient background to understand complexities associated with an industrial MPC scheme or undertake further research and development in this area.

COURSE DETAIL

Lecture (1.5 hrs)	Lecture Title and Topics Covered
1	**Introduction and Motivation**
	Development of Control Relevant Linear Perturbation Models
2	Topic: Development of Control Relevant Linear Perturbation Models Sub-topic: Linearization of Mechanistic Models
3	Topic: Development of Control Relevant Linear Perturbation Models Sub-topic: Linearization of Mechanistic Models (Contd.)
4	Topic: Development of Control Relevant Linear Perturbation Models Sub-topic: Introduction to z-transforms and Development of Grey-box models

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Chemical Engineering

Pre-requisites:

- Basic courses on Engineering Mathematics covering fundamentals of calculus, linear algebra and ordinary differential equations
- Familiarity with dynamic models used in engineering problems
- A first course in process control or control theory covering concepts of Laplace transforms, SISO transfer functions, frequency domain stability analysis and design of PID controllers

Additional Reading:

- Gilbert Strang , *Introduction to Applied*

	Development of Linear Black-box Dynamic Models
5	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topic: Introduction to Stability Analysis and Development of Output Error Models
6	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topic: Introduction to Stochastic Processes
7	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topic: Introduction to Stochastic Processes (Contd.)
8	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topic: Development of ARX models
9	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topics: Statistical Properties of ARX models and Development of ARMAX models
10	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topics: Development of ARMAX models (contd.) and Issues in Model Development
11	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topics: Model Structure Selection and Issues in Model Development (contd.)
12	Topic: Development of Control Relevant Linear Perturbation Models (Part 2) Sub-topics: Issues in Model Development (contd.) and State Realizations of Transfer Function Models
	Stability Analysis, Interaction Analysis and Multi-loop Control
13	Topic: Stability Analysis of Discrete Time Systems
14	Topic 1: Stability Analysis of Discrete Time Systems - Lyapunov Functions Topic 2: Interaction Analysis and Multi-loop Control
15	Topic: Interaction Analysis and Multi-loop Control (contd.)
	State Estimation and Kalman Filtering
16	Topic 1: Multivariable Decoupling Control Topic 2: Soft Sensing and State Estimation
17	Topic: Soft Sensing and State Estimation Sub-Topic: Development of Luenberger Observer

Mathematics, Wellesley Cambridge Press (2009)
- Ljung, L., Glad, T., Modeling of Dynamic Systems, Prentice Hall, N. J., 1994.
- Soddersto rm and Stoica, System Identification, Prentice Hall, 1989.
- Soderstrom, T. Discrete Time Stochastic Systems, Springer, 2002.
- Gelb, A. Applied Optimal Estimation, MIT Press, 1974

Coordinators:

Prof. Sachin C. Patwardhan
Department of Chemical EngineeringIIT Bombay

18	Topic: Soft Sensing and State Estimation Sub-Topics: Development of Luenberger Observer (contd.) and Introduction to Kalman Filtering
19	Topic: Soft Sensing and State Estimation Sub-Topic: Kalman Filtering
20	Topic: Soft Sensing and State Estimation Sub-Topic: Kalman Filtering (contd.)
21	Topic: Soft Sensing and State Estimation Sub-Topic: Kalman Filtering (contd.)
	Linear Quadratic Optimal Control and Model Predictive Control
22	Topic: LQG and MPC Sub-Topic: Pole Placement State Feedback Control Design and Introduction to Linear Quadratic Gaussian (LQG) Control
23	Topic: LQG and MPC Sub-Topic: Linear Quadratic Gaussian (LQG) Regulator Design
24	Topic: LQG and MPC Sub-Topic: Linear Quadratic Gaussian (LQG) Controller Design
25	Topic: LQG and MPC Sub-Topic: Model Predictive Control (MPC)
26	Topic: LQG and MPC Sub-Topic: Model Predictive Control (contd.)

References:

- Astrom, K. J., and B. Wittenmark, Computer Controlled Systems, Prentice Hall India (1994).
- Franklin, G. F., Powell, J. D., and M. L. Workman, Digital Control Systems, Addison Wesley, 1990.
- Process Dynamics and Control, D. E. Seborg, T. F. Edgar, D. A. Mellichamp, Wiley, 2003.
- Control System Design, by Graham C. Goodwin, Stefan F. Graebe, Mario E. Salgado, Prentice Hall, 2000.