**Modeling and Control for Process Industry**

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| **Cds:**  Master in Chemical Engineering | **Lecturer:**  Prof. Michele MICCIO | **Academic year:**  2017-18 | **Codice**: 0622200004 |  |
| **h Th:** 36 | **h Ex:** 3 | **h Lab:** 21 |  |  |

# Educational goals:

## Knowledge and understanding:

The course aims at providing students with the fundamentals, methodologies and software tools for affirming the stability of linear process systems under feedback automatic control, other general knowledge on automatic control of industrial processes, tools for classification and development of mathematical models, basic knowledge for understanding the dynamics and stability of nonlinear systems that frequently represent cases and problems of process engineering.  
Students acquire:

The English terminology used in the theory and technology of modern automated industrial process control, not just feedback.  
Knowledge of possible classifications for general mathematical models and for dynamical systems in particular.  
Definition of stability for dynamical systems with both input-output and state-space representation, both linear and non-linear ones.  
Meaning and implications that the approach, either continuous or discrete, to time representation involves in dynamical systems.  
Ability to distinguish the level of complexity needed for the system description of process industry facilities and to select the mathematical techniques and tools for their abstract representation.

## Applying knowledge and understanding – engineering analysis:

Know how to classify mathematical models.

Understand the meaning and implications that representation of dynamical systems in a continuous or discrete time domain involves.

Be able of distinguishing the level of complexity that is appropriate for a process industry system description when one aims at developing and solving the related mathematical model.

## Applying knowledge and understanding – engineering design:

Build the Root Locus, Bode and Nyquist diagrams with the use of software, specifically the Matlab® Control Toolbox.  
Check and discuss the BIBO stability of a linear dynamic feedback system, also in the case the parameters of the PID controller are changed.

## Making judgments - engineering practice:

Discrimination between stable, marginal stable and unstable linear dynamic systems.  
Know how to recognize the most common linear dynamic systems causing closed loop BIBO instability and take the necessary countermeasures.  
Be prepared to catch behavioral differences, both conceptual and practical, in regime and regime dynamic conditions, between linear and nonlinear systems.

## Communication skills – transversal skills:

Understand the terminology used in English for development and application of mathematical models.  
Know how to apply the acquired knowledge to contexts that are different from those presented during the course and to deepen the topics by resorting to study materials other than the ones presented in the course.

## Learning skills – transversal skills:

For a linear feedback control problem:  
Know how to evaluate the features and benefits of actions that a PID controller performs in relation to BIBO stability.  
Know how to deal with and represent a problem in a computer-aided framework, but under a limited time allowance.

# Prerequisites

For the successful achievement of the prefixed objectives, a basic mathematical knowledge is required, in particular on ordinary and partial differential equations, mastery of mass and energy balances under non-stationary conditions and fundamentals of transport phenomena.

# Contents

Introduction to the specific software. Preliminary notes on MatLab®¸ with its Control Toolbox and SisoTool® desktop. H Th. 0, h Ex. 0, h Lab. 4  
Root locus: BIBO stability study with direct and inverse Root locus. H Th. 6, h Ex. 0, h Lab. 4  
Frequency response: AR and phase; Bode diagrams. BIBO stability study by frequency response; Bode's stability criterion; Gain and phase margins. Nyquist diagrams; Nyquist's stability criterion. H Th. 7, h Ex. 0, h Lab. 5  
Discussion of other problems, strategies or architectures in control: autotuning, selftuning. Wind-up of the integrator. Inverse response systems. Smith's Predictor. Positive feedback. Feedforward, cascade, ratio, adaptive, multivariable, inferential control. Hints on model-based predictive control (MPC). H Th. 6, h Ex. 0, h Lab. 2  
Modeling and simulation: Classification of general models and the mathematical ones in greater detail. Hints on models based on the "population balance". Hints on time series. H Th. 11, h Ex. 3, h Lab 2.  
Introduction to dynamic analysis of nonlinear systems: Representation of dynamic systems in the state space. Autonomous systems. Diabatic CSTR. Constant and dynamic asymptotic regimes. Solution diagram. Concept of stability and asymptotic stability according to Lyapunov. Stability study of autonomous linear dynamical systems of the 1st and 2nd order. Logistic Map. Hints on deterministic chaos. Hints on the concept of bifurcation. H Th. 6, h Ex. 0, h Lab. 4.

# Educational methods

The course is held in English.  
Teaching involves theoretical lectures conducted by the lecturer with extensive use of computerized slides and animations, exercises carried out by the lecturer on the blackboard and computer lab classes conducted by the lecturer interactively with the students, through the use of appropriate learning software. Each student is assigned a user name and a password, allowing access in the computer classroom to networked PCs provided with MatLab® license with its Control Toolbox and SisoTool® desktop.  
All course slides, other notes and texts of previous written exams are made available by the lecturer.

# Learning assessment:

The achievement of the prefixed goals is assessed by means of two tests, which the student may ask to do even distant over time:  
1) a practical test on the BIBO stability of linear dynamic feedback systems. The test involves performing an essay directly on PC, in MS Word®, and embodying the results obtained with MatLab® and the Control Toolbox, while keeping all the course material at fingertips. The practical test is passe with the lowest score (18/30) if the student has used at least one of the methods on the BIBO stability of linear dynamic feedback systems and at the same time provided correct answers to 60% of the questions.  
2) a subsequent oral interview that focuses on advanced control, mathematical modeling and nonlinear dynamical systems; during this oral interview, the student is expected to demonstrate the comparative knowledge, applied comprehension capacity and critical judgment autonomy as described in the prevoius paragraphs.  
In order to get the mark “cum laude”, both the quantity (comprehensive and numerically correct answers to about 90% of the questions) and the quality (appropriate scientific language and mastery of the subject) are taken into account of both written and oral expositions.

# Textbooks:

Magnani G., P. Ferretti e P.Rocco, “Tecnologie dei Sistemi di Controllo”, 2° ed., ISBN 88 386 6321-1, McGraw-Hill Libri Italia

Stephanopoulos G., “Chemical process control: an introduction to theory and practice”, Prentice Hall, ISBN 0131286293, 1983

Chau P. C., “Process Control - A First Course with MATLAB®”, ISBN-13: 9780521002554, ISBN-10: 0521002559, Cambridge University Press, 2002

Palazoglu A. and Romagnoli J.A., "Introduction to Process Control (Chemical Industries)", ISBN: 0849334969, CRC Press, 2005

# Other info:

WEB site for personal study and outcome of exams:

<http://comet.eng.unipr.it/~miccio>