SYLLABUS

1. Information regarding the programme

1.1 Higher education institution	Babeş–Bolyai University of Cluj–Napoca
1.2 Faculty	Chemistry and Chemical Engineering
1.3 Department	Chemical Engineering
1.4 Field of study	Chemical Engineering
1.5 Study cycle	Master
1.6 Study programme / Qualification	Advanced Chemical Process Engineering

2. Information regarding the discipline

2.1 Name of the discipline	**Advanced Process Control (Automation and Evolved Management of Chemical Processes)– CME7322**				
2.2 Course coordinator	Prof.dr.ing. Cristea Vasile Mircea				
2.3 Seminar coordinator	Prof.dr.ing. Cristea Vasile Mircea				
2.4. Year of study	I	2.5 Semester	2	2.6. Type of evaluation	WE	2.7 Type of discipline	DF/Obl.

3. Total estimated time (hours/semester of didactic activities)

3.1 Hours per week	4	Of which: 3.2 course	2	3.3 seminar/laboratory	2
3.4 Total hours in the curriculum	56	Of which: 3.5 course	28	3.6 seminar/laboratory	28

Time allotment:	hours
Learning using manual, course support, bibliography, course notes	25
Additional documentation (in libraries, on electronic platforms, field documentation)	18
Preparation for seminars/labs, homework, papers, portfolios and essays	20
Tutorship	3
Evaluations	3
Other activities:	-

3.7 Total individual study hours	69
3.8 Total hours per semester	125
3.9 Number of ECTS credits	5

4. Prerequisites (if necessary)

4.1. curriculum	• Basic Process control, Basic Chemical Engineering.
4.2. competencies	• Basic computer using skills (Matlab).

5. Conditions (if necessary)

5.1. for the course	• Presence at classes favours the final notation.
5.2. for the seminar /lab activities	• Minimum average allowed for entering the examination is 5. • All lab hours and seminar are compulsory.

6. Specific competencies acquired

Professional competencies	• capacity of conceiving a control system dedicated to a specific process, capacity of conceiving and writing a mathematical model of high complexity dedicated to a certain specific process, capacity of choosing a an appropriate control solution based on the analysis of the process model, economic analysis of efficiency of the chosen control solution, capacity of operating a complex plant
Transversal competencies	• ability of systemic thinking, holistic thinking, critical thinking, argumentative, problem solving orientation, high level of computer skills, analysis of a process based on a mathematical model.

7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	• To make the student understand the behaviour of a complex process based on a mathematical model and to implement a control scheme
7.2 Specific objective of the discipline	• To develop a control system adequate to a specific process

8. Content

8.1 Course	Teaching methods	Remarks
8.1.1. **Cascade control. Feedforward control. Examples.** *Basic concepts, key words*: controllability, cascade, disturbance, parameters' tuning, energy consumption saving.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.2. **Feedforward control, Ratio control , Inferential control. Examples**. *Basic concepts, key words*: Feedforward, ratio, inferential control, economic justification.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.3. **Automatic control of the main process parameters. Examples**. *Basic concepts, key words*: temperature control, pressure control, level control, flow control, concentration control.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.4. **Chemical reactors' control. Types of reactors. Thermal instability of the reactors. Temperature control for the thermally unstable and stable reactors. Examples.** *Basic concepts, key words*: reaction kinetics, reaction rate, conversion, equilibria, enthalpy, thermal instability, Continuous Stirred Tank Reactor, Plug Flow Reactor, Mass Transfer Reactor, Electrochemical Reactor.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.5. **Chemical reactors' control.** *Basic concepts, key words*: steady state mathematical model, continuous /batch stirred tank reactors, plug flow reactors, mass transfer reactors, electrochemical reactors, microreactors, control design scheme.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.6. **pH control. Control of the**	Lecture	PowerPoint

distillation/rectification processes. Control of the distillation/rectification processes. *Basic concepts, key words*: pH, instability. Economic considerations of the distillation processes, high value product recovery, material and energy balances, continuous/batch distillation.	Computer simulations Power point presentations Interactive exercises	presentations, Matlab and Toolboxes for exemplification and applications.
8.1.7. **Control of the distillation/rectification absorption/ desorption processes. Control of extraction processes.** *Basic concepts, key words*: : Material and energy balances, control schemes. Absorption/ desorption, mathematical model, exothermal processes, liquid- liquid extraction, solid-liquid extraction, separation interface.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.8. **Control of the drying process.** *Basic concepts, key words*: relative and absolute humidity, psychometric method, adiabatic drying.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.9. **Control of bioprocesses.** *Basic concepts, key words*: biochemical reactors, biomass, drying at low temperatures, mathematical model, sensitivity, control schemes.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.10. **Control of the thermally integrated processes.** *Basic concepts, key words*: controllability, instability, thermally integrated systems dynamics, economic analysis.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.11. **Linear Model Predictive Control (MPC)**; optimisation with constraints. MPC Tuning. *Basic concepts, key words*: models, objective function, constraints, linear programming, quadratic programming, explicit solution, weighting matrices.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.12. **Nonlinear Model Predictive Control (MPC)**; optimisation with constraints, stability, adaptive MPC, hierarchical MPC, linearization. *Basic concepts, key words*: continuous/discrete models, linearization, sequential and simultaneous nonlinear programming methods, end-point (terrminal) terms (constraints).	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.13. **Control systems implementing fuzzy-logic.** *Basic concepts, key words*: fuzzy sets, membership functions, fuzzy rules, fuzzification, inference, defuzzification, control.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
8.1.14. **Control systems based on Artificial Neural Networks (ANNs).** *Basic concepts, key words*: dynamic models built with ANNs, MPC using ANN models.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.

Bibliography

1. Paul Şerban Agachi, Mircea Vasile Cristea, Alexandra Ana Csavdári, Botond Szilágyi, Advanced Process

Engineering Control, De Gruyter Publishing House, Editura De Gruyter GmbH, Berlin, 2016,

2. Agachi P.S., Cristea M.V, Basic Process Engineering Control, Editura De Gruyter GmbH, Berlin, ISBN: 978-3-11-028981-7, e-ISBN: 978-3-11-028982-4, 360 p., 2014,

3. V. M. Cristea, S. P. Agachi, *Elemente de Teoria Sistemelor*, Editura Risoprint, Cluj-Napoca, 2002,

4. P.S. Agachi, Z.K. Nagy, M.V. Cristea, A. Imre-Lucaci – *Model Based Control, Case studies in process engineering*, Ed. Wiley-VCH, Weinheim, 2006.

5. V. M. Cristea PowerPoint presentations of the courses.

Supplementary Bibliography

6. F. Greg Shinskey - *Process Control Systems Application, Design and Tuning*, Ed. Mc.Graw Hill, New York, 1996,

7. Paul Serban Agachi – *Automatizarea Proceselor Chimice*, Ed. Casa Cărţii de Stiinţă, Cluj-Napoca, 1994,

8. P. Serfelis, M.C. Georgiadis, *The Integration of Process Design and Control*, Elsevier, 2004.

Note: titles can be accessed at the Library of the Department of Chemical Engineering of the Faculty of Chemistry and Chemical Engineering, at the Central University Library "Lucian Blaga" and at the Library of the Technical University of Cluj

8.2 Seminar / laboratory	Teaching methods	Remarks
8.2.1. **Cascade control. Design.** *Basic concepts, key words*: temperature cascade control, flow ratio control, parameters tuning.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.2. **Ratio control. Design.** *Basic concepts, key words*: temperature cascade control, flow ratio control, parameters tuning.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.3. **Feed forward of a CSTR**. **Design.** *Basic concepts, key words*: disturbance, disturbance transducer, disturbance controller, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.4. **Feedback and feedforward of a CSTR**. **Design.** *Basic concepts, key words*: disturbance, disturbance transducer, disturbance controller, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.5. **Feedforward control of a distillation column. Control of a binary distillation column.** *Basic concepts, key words*: heat transfer, mass transfer, impulse transfer, feed disturbance, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.6. **Control of the bio-reactor.** *Basic concepts, key words*: bioreactor, mass of reaction, bio-mass, reaction kinetics, analysers, control structures.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.7. **Control of the Waste Water Treatment Plant WWTP (I).** *Basic concepts, key words*: modelling nitrification and denitrification bioreactors, bioreaction kinetics, control structures.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.8. **Control of the Waste Water Treatment Plant WWTP (II).** *Basic concepts, key words*: control of the settler (secondary and primary), aeration control strategies, control for	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.

minimizing energy costs and maximizing effluent quality.		
8.2.9. **Developing application for MPC with and without constraints,** using both CETM and command prompt. Simulink implementation. Tuning SISO and MIMO MPC. *Basic concepts, key words*: nonlinear process, Simulink MPC block, tuning, stability, command prompt developed MPC.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.10. **MPC Control of the Fluid Catalytic Cracking Unit (I)** *Basic concepts, key words*: heat transfer, mass transfer, impulse transfer, feed disturbance, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.11. **MPC Control of the Fluid Catalytic Cracking Unit (II)** *Basic concepts, key words*: Control of the riser, stripping vessel, regenerator, air blower, wet-gas compressor, main fractionator.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.12. **Application and implementation demonstration of a Fuzzy Controller, using Fuzzy Logic Toolbox.** *Basic concepts, key words*: fuzzy sets, membership functions, fuzzy rules, fuzzification, inference, defuzzification, control.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.13. **Application and implementation demonstration of MPC using ANN models (I).** *Basic concepts, key words*: training, dynamic ANN, nonlinear model.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
8.2.14. **Application and implementation demonstration of MPC using ANN models (II).** *Basic concepts, key words*: FCCU application, drying electric insulators.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.

Bibliography

1. Paul Şerban Agachi, Mircea Vasile Cristea, Alexandra Ana Csavdári, Botond Szilágyi, Advanced Process Engineering Control, De Gruyter Publishing House, Editura De Gruyter GmbH, Berlin, 2016,

2. G. Stephanopoulos, Chemical Process Control An Introduction to Theory and Practice, Prentice Hall, 1984,

3. Mihaela Iancu, P.Ş.Agachi, M.Mogoş, M.Cristea, Automatizarea Proceselor Chimice – Lucrări de Laborator, Presa Universitară Clujeană, UBB, 2012.

Supplementary Bibliography

4. *Control System Toolbox,* Matlab, Documentation accompanying toolbox,

5. *Model Predictive Control Toolbox,* Matlab, Documentation accompanying toolbox,

6. *Fuzzy Logic Toolbox,* Matlab, Documentation accompanying toolbox,

7. Paul Serban Agachi – Automatizarea Proceselor Chimice, Ed. Casa Cărţii de Ştiinţă, 1994.

9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

- Curriculum was elaborated after consultancy with the PC groups from the universities in Iasi, Bucuresti, Ploieşti and Timişoara

- Process Engineering was introduced based on a WB program of Computer Aided Process Engineering (1998-2002)
- The competencies and qualifications have been set in accordance to the Diploma Supplement and qualifications of the National Authority of Qualifications standards

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	Understanding of the processes discussed Specificity of the answers Holistic thinking and approach	On-site or online examination method. The examination consists in the elaboration of a paper in which answers will be given to the subjects (questions / problems) from the course topic. Access to the exam is conditioned by the presentation of the solutions to the received homeworks. Fraud intention at the exam is punishable by removal from the exam. Fraud of the examination is punishable by removal from the examination and by expulsion according to the ECB regulations of the UBB.	75
10.5 Seminar/lab activities	Understanding of the discussed processes. Specificity of the answers. Holistic thinking and approach.	On-site or online evaluation. The solved homeworks are presented at the next seminar meeting. Examination during the seminar.	10
	Ability to use different sources of information.		5
	Quality of solved homework / tests.		10
10.6 Minimum performance standards			
• Obtaining a minimum grade of 5 (five) both in the evaluations related to the course, seminar, solving the received homeworks. • Obtaining the minimum grade 5 (five) both in the evaluation of the theoretical part and the problem part, in the examination.			

Date	Signature of course coordinator	Signature of seminar coordinator
10.04.2021	Cristea V.M.	Cristea V.M.

Date of approval   Signature of the Director of the Department

April 25, 2021

                                          Prof. dr. eng. Turdean Graziella