SLOVAK UNIVERSITY OF TECHNOLOGY
IN BRATISLAVA

FACULTY OF CHEMICAL AND FOOD
TECHNOLOGY

INSTITUTE OF INFORMATION ENGINEERING, AUTOMATION,
AND MATHEMATICS

DEPARTMENT OF INFORMATION ENGINEERING AND PROCESS CONTROL

ANNUAL REPORT

2019

Address:

Department of Information Engineering and Process Control
Institute of Information Engineering, Automation, and Mathematics

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Absent: J. Mikleš, A. Vasičkaninová

Contents

1 Preface

The Department of Information Engineering and Process Control at the Faculty of Chemical and Food Technology of the Slovak University of Technology in Bratislava has more than a fifty-year tradition in conducting teaching and research. It educates highly qualified specialists in the field of process control for design, implementation, and application of control systems. The educational pyramid includes a three year bachelor study in the study programme called Information Engineering, Automation and Management in Chemical and Food Industry, a 2-year master study in the programme Information Engineering and Automation in Chemical and Food Industry, and a four year PhD study in the programme Process Control.

Nowadays, information technologies and advanced process control systems represent important and acknowledged scientific branches. These branches significantly influence the economic and social growth in the whole world and successively also in Slovakia. The chemical, food processing, and pharmaceutical industries with their technologies are no exceptions. No technology is able to be successful in the competition without optimization and advanced control systems or without using information technologies.

The main branch of teaching and research activities of the department is oriented towards process control, optimization-based control design, identification and modeling of dynamical systems, industrial automation, and on the development of software packages for intelligent control systems. The second branch is devoted to information technologies, data management, and programming.

Our department therefore prepares our graduates to be competitive in this dynamical and demanding environment. As a sign of our success, let me just point out zero unemployment rate of our graduates during the whole history of our department. The graduates of the department do well not only in companies and institutions oriented on the design and installation of control systems for various technologies, but also in the fintech sector, or as founders of their own companies.

Recently, I was honoured to become the new head of the department. At this point let me express my gratitude to the previous head – prof. Miroslav Fikar, DrSc. – who has established solid foundations upon which the department can grow further. I also wish to thank all the talented people at my department with whom I am profoundly proud to work with. To further improve the department, my personal goal is to increase the participation of the entire department in various research, project proposals and industrial cooperation in 2020.

I am also glad to report that the Academic Senate of our university has elected prof. Ing. Miroslav Fikar, DrSc. for the rector of the university for the period 2019–2023. Moreover, doc. Monika Bakošová CSc. has been approved by Academic Senate of STU as the vice-rector for education for the period 2019–2023. I wish them a lot of success in their new positions.

doc. Ing. Michal Kvasnica, PhD.

2 Introduction

This report summarizes the teaching and research activities at the Department of Information Engineering and Process Control at the Faculty of Chemical and Food Technology at the Slovak University of Technology in Bratislava during the period January 1st – December 31st of 2019.

Department of Information Engineering and Process Control of the Faculty of Food and Chemical Technology (FCFT), Slovak University of Technology in Bratislava was constituted from the Department of Measuring and Control Technique of the Faculty of Electrical Engineering of the Slovak University of Technology in Bratislava in 1962. Because of the specific control problems of the processes and systems in the chemical and biochemical technologies, the specialization Process Control in the frame of the study branch Chemical Engineering and Process Control has been established. Students and postgraduate students have been educated since 1964. So far, more than four hundred specialists and almost thirty PhD students have been graduated here and four professors and nine associated professors have been appointed. Since 2005, Department of Information Engineering and Process Control and Department of Mathematics have formed Institute of Information Engineering, Automation, and Mathematics.

The first head of the department was Prof. Daniel Chmúrny, DrSc in 1962 – 1986. Prof. Ján Mikleš, DrSc headed the department in 1986 – 1994 and in 1998 – 2003. The head in 1995 – 1997 was prof. Alojz Mészáros, PhD and prof. Ing. Miroslav Fikar, DrSc. was head of the department in 2003 – 2019. New head of the department is doc. Ing. Michal Kvasnica, PhD.

Department of Information Engineering and Process Control is one of the 22 departments at the FCFT STU, where students obtain specialization in various branches of chemical technology or chemical engineering. Approximately 2,000 students are currently enrolled in the three-year bachelor programs leading to the Bc. degree and two-year master programs leading to the Ing. degree, which is equivalent to the M.Sc. degree. The best ones continue in the four-year doctoral programs leading to the PhD degree.

3 Staff

3.1 Department Administration

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4 Teaching and Research Laboratories

Laboratory of Process Control: Control of specific processes via Matlab and internet access (elab)

- Distillation Column Armfield UOP3CC (elab)
- Membrane Process SUPER RO BM 30 (elab)
- Multifunction Station Armfield PCT40 (elab)
- Hydraulic System with Storage Tanks DTS200
- Training Station Armfield PCT23 (elab)
- Small-scale Fuel Cell

Laboratory of Control Systems:

- Lego Mindstorms NXT 2.0
- Thermo-optical System uDAQ28/LT
- Ball & Plate CE 151
- Magnetic Levitation
- Flexy
- Laboratory Food Machine
- Linear Inverted Pendulum
- Rotary Inverted Pendulum (Furuta)

Laboratory of Industrial Technology:

- Siemens-SIMATIC S-7 200, 300, 1200
- FOXBORO
- B&R
- VIPA 300S
- eWONx005CD
- Experion/Honeywell

Computer Laboratories:

- Linux based PCs
- Raspberry Pi
- Arduino
- Moving Robots (cars)
- 2D Plotter
- 3D Printer

Remote Laboratories: Control of technological processes via internet access

- Thermal-optical systems
- DC motor

5 Educational Activities

5.1 Bachelor Study

1st semester (Winter)		
Fundamentals of Matlab	0/0/2	Oravec
2nd semester (Summer)		
Information Engineering and Systems	1/2/0	Čirka
3rd semester (Winter)		
Fundamentals of Language C	0/0/2	Furka, Kvasnica
Fundamentals of Matlab	0/0/2	Furka, Horváthová, Kiš, Valero
Linux – Basic Automation	0/0/2	Valo
Modelling	2/0/3	Mészáros, Vasičkaninová
Operating Systems	0/0/2	Valo
4th semester (Summer)		
Fundamentals of Embedded System Control	0/0/2	Kalúz
Introduction to Process Control	1/0/1	Klaučo, Valiauga
Laboratory Exercises of Process Control	0/0/2	Oravec, Valiauga, Vasičkaninová
Process Control	2/0/0	Bakošová
Programming I	2/0/2	Bakaráč, Kvasnica
Spreadsheet and Database Systems for Data Processing	0/0/2	Čirka
Web Technologies in Automation	0/0/2	Valo
5th semester (Winter)		

Design of Information and Control Systems	2/0/3	Valo
Fundamentals of Matlab	0/0/2	Valero
Optimization	2/0/2	Horváthová, Klaučo

6th semester (Summer)

Fundamentals of Electrotechnics	0/2/0	Valo
Integrated Control in Process Industries	2/0/3	Bakošová, Vasičkaninová
Internet and Information Systems	0/0/2	Čirka
Laboratory Exercises of Process Control	0/0/2	Oravec, Valiauga, Vasičkaninová
Process Control	2/0/0	Bakošová
Programming II	1/2/0	Bakaráč, Kvasnica
Remote Control of Embedded Systems	0/0/2	Kalúz

5.2 Master Study

1st semester (Winter)

Automatic Control Theory I	2/0/3	Fikar, Klaučo, Paulen, Valero
Control of Technological Processes	1/0/1	Bakošová, Oravec, Vasičkaninová
Industrial Control Systems	0/0/2	Valo
Information Technology I	0/0/2	Mojto
Modelling in Process Industry	2/2/0	Bakošová, Valiauga, Vasičkaninová
Object Oriented Programing	1/0/3	Kiš
Process Dynamics and Control	2/0/1	Bakošová, Vasičkaninová
Programming of Web Applications	1/0/2	Čirka

Technical Means of Automation	2/0/2	Bakaráč, Kalúz
2nd semester (Summer)		
Automatic Control Theory II	2/0/3	Fikar, Klaučo
Control of Technological Processes	1/0/1	Bakošová, Oravec, Vasičkaninová
Identification	2/0/2	Čirka, Fikar
Informatization Engineering and Systems I	1/0/3	Kalúz, Valo
Matlab - Advanced Techniques	1/0/1	Valo
3rd semester (Winter)		
Automatic Control Theory III	2/0/2	Fikar, Valiauga
Creation of Scientific Documents	0/2/0	Mojto
Industrial Control Systems	0/0/2	Valo
Information Engineering and Systems II	2/0/2	Čirka
Information Technology I	0/0/2	Mojto
Optimisation of Processes and Plants	2/0/2	Horváthová, Kvasnica
Process Control Project	0/0/3	Kalúz, Klaučo
Process Dynamics and Control	2/0/1	Bakošová, Vasičkaninová
Project Software Systems	0/2/0	Oravec
Robotic Process Automation	0/0/3	Čirka, Kalúz
4th semester (Summer)		
Intelligent Control	1/2/0	Mészáros
Matlab - Advanced Techniques	1/0/1	Valo
Predictive Control	1/2/0	Klaučo, Kvasnica
Robust Control	1/2/0	Bakošová, Oravec

5.3 PhD Study

1st year

Modelling and Control of Biotechnological Processes	2/0/3	Bakošová
Modelling and Control of Chemical Processes	2/0/3	Bakošová
Optimal Control	2/0/3	Fikar
Advanced Predictive Control	2/3/0	Kvasnica
Selected Topics in Intelligent Control	2/0/3	Fikar
Selected Topics in the Theory of Automatic Control	2/0/3	Paulen

5.4 Course Contents

5.4.1 Lectures in Bachelor Study

Information Engineering and Systems (1h/week, 2nd semester) Static and dynamic pages, web technologies – HTML and XHTML, creation of html documents. XHTML: structure of XHTML document (head, body). XHTML: text, links, numbered and unnumbered lists. XHTML: graphics, tables. XHTML: forms (methods, form elements, attributes), evaluation of form data. XHTML: frames, applets, servlets. CSS: introduction to formatting using cascade styles. CSS: colour, font, alignment, links. CSS: numbered and unnumbered lists, borders, background. CSS: classes and identifiers. Practical webdesign: planning, design (effective navigation, colours, text, graphics, animations), publishing, maintenance. Google - search, Gmail, YouTube, Picasa, Blogger, Talk, Earth, Maps. Google - Images, Video, Book Search, Calendar, Documents, Notebook.

MATLAB – Advanced Techniques (1h/week, 2nd semester) Introduction to MATLAB. Basic architecture of MATLAB. Functions I. Functions II. Functions III. Functions for working with data. Symbolic toolbox. Introduction to Object-Oriented Programming. Graphics objects. GUIDE – graphical user interface.

Low-level input and output. HTTP MATLAB Web Server I. HTTP MATLAB Web Server II.

Modelling (2h/week, 3rd semester) Introduction to process modelling, approaches to modelling, types of mathematical models. Static and dynamic mathematical models of basic types of processes in chemical and food technology: tanks, mixers, various types of heat exchangers, continuous stirred tank reactors. Simulation of the static and dynamic behaviour of selected processes in chemical and food technology using the simulation software MATLAB – Simulink.

Introduction to Process Control (1h/week, 4th semester) Modelling of tanks. Modelling of heat exchangers. Modelling of a chemical reactor. On-off controller. PID controller. Feed-back control loop. Stability. Reference tracking and disturbance rejection. Control performance. Analytical methods for controller synthesis. Experimental methods for controller synthesis. Technological schemes with measurement and control loops.

Process Control (2h/week, 4th semester) Laplace transform. Transfer function and transfer functions of complex systems. Step response. Impulse response. Poles and zeros. Modelling of tanks. Modelling of heat exchangers. Modelling of a chemical reactor. On-off controller. PID controller. Feed-back control loop. Stability. Reference tracking and disturbance rejection. Control performance. Analytical methods for controller synthesis. Experimental methods for controller synthesis. Measurement of process variables. Technological schemes with measurement and control loops.

Programming I (2h/week, 4th semester) Python syntax and semantics, data types, variables and constants, Python control instructions, static single and multidimensional arrays, file handling, matrix operations.

Design of Information and Control Systems (2h/week, 5th semester) The course is divided into two major parts. The first one covers synthesis of simple controllers based on logic rules, their representation using finite state machines, as well as their implementation in Stateflow. The second part is devoted to implementation of logic control on Programmable Logic Controllers using Ladder logic.

Introduction to XML Technologies (1h/week, 5th semester) Introduction to XML, examples of practical use, XML document structure and writing, industry-derived XML standards, XML document validation using DTD, XPATH search, XSLT transformation.

Optimization (2h/week, 5th semester) Unconstrained optimization methods. Constrained optimization methods. Linear Programming. Quadratic Programming. Dynamic Programming. Advanced Optimization Methods.

Integrated Control in Process Industries (2h/week, 6th semester) Process identification from aperiodic or periodic step response. Feedback and feedforward control. Complex control structures: cascade control, complex control structure with disturbance measurement, complex control structure with auxiliary control input, time-delay compensator – Smith predictor and its modifications, ratio control. Process control: control of tanks, control of mixing units, control of heat exchangers, control of distillation columns, control of chemical reactors, control of dryers. Basic principles of advanced control methods: adaptive control, robust control, predictive control, fuzzy control, artificial neural networks in process control.

Programming II (1h/week, 6th semester) Students should learn to develop learned basic programming in C/C++. Working with arrays and matrices, initialization and allocation of arrays. Input and output to a file, work with command line. Working with strings and simple data structures. Familiarity with the structures. Design and implementation of custom algorithms.

5.4.2 Laboratory Exercises in Bachelor Study

Fundamentals of Matlab (2h/week, 1st semester) Introduction to MATLAB and Simulink. Variables, expressions, and operators. Matrices and vectors. Elementary mathematical functions. MATLAB graphics – 2D charts. MATLAB graphics – 3D charts. Polynomials. Custom application design. Symbolic Math Toolbox.

Fundamentals of Electrotechnics (2h/week, 2nd semester) Electric circuits – voltage, current. Electric circuits – passive elements. Electric circuits – active elements. Analysis of electrical circuits. Measurement of electrical circuits. Signal transmission. Signal processing. Measurement of electrical signals –

Waveform. Sensors of non-electrical quantitie. Interconnection of sensors and control elements.

Information Engineering and Systems (2h/week, 2nd semester) The curriculum of exercises follows the topics of lectures of this course.

Internet and Information Systems (2h/week, 2nd semester) Information Systems – introduction. Analysis and design of information system. Static websites I – HTML. Static websites II – XHTML. Websites formatting I – CSS. Websites formatting II – CSS. Content Management Systems (CMS, LMS ...). Webhosting and services. Internet services. Cloud computing. Ecommerce. Safety on the Internet. Virtual and remote laboratories.

MATLAB – Advanced Techniques (1h/week, 2nd semester) The curriculum of exercises follows the topics of lectures of this course.

Spreadsheet and Database Systems for Data Processing (2h/week, 2nd semester) Introduction to relational databases. MS Access and MySQL. Database design. Database normalization (1NF, 2NF, 3NF, ...). Table creation (fields, data types, indexes, field properties, update). Forms and their elements. Queries. Basics of SQL. Reports. Simple practical application using database. Data processing in a spreadsheet editor (MS Excel). Data processing function. Pivot tables and pivot charts.

Modeling (3h/week, 3rd semester) The curriculum of exercises follows the topics of lectures of this course.

Operating Systems (2h/week, 3rd semester) Introduction to operating systems of computers. Multitasking, types of multitasking and their comparison. Linux – operation system of UNIX-type, its installation. Free and Open Source Software, GNU Foundation. Introduction to Solaris operating system. Basic file and directory operations, editing, searching, regular expressions, makefiles. Introduction to computer typesetting. Remote computers, communication tools: telnet, ssh, ftp, http, smtp.

Fundamentals of Language C (2h/week, 3rd semester) The course introduces students to basic concepts and fundamentals of the C programming

language. Covered topics include: allocation of variables, standard output to screen, standard input from the keyboard, string functions, if-then-else conditions, FOR and WHILE loops, arrays, matrices and user-defined functions. Each covered topic is accompanied with illustrative examples and sample problems for practicing.

Linux – Basic Automation (2h/week, 3rd semester) Bash – recapitulation. Introduction to scripting. Simple tasks – variables, cycles, conditions. Algorithms for more complex tasks. Own script. Presentation.

Fundamentals of Embedded System Control (2h/week, 4th semester) Embedded systems – general introduction, characterization, usage in practice. Interaction between embedded system and outside world – introduction to sensors (types and their usage) and actuators (types and their usage). Microcontrollers - general introduction, types and area of usage, principles of operation, advantages and limitations. Microcontrollers – communication scenarios with microcontrollers, programming languages, introduction to programming environment. Introduction to programming language. Programming methods for microcontrollers. Implementation of control logic – introduction to the control algorithms, logical controllers, digital implementation of the PSD controller, digital implementation of the state-space controller and transfer function. Practical applications : object distance measurement using ultrasound. Practical applications : implementation of closed control loops. Realization of final project. Presentation of final project.

Introduction to Process Control (1h/week, 4th semester) The curriculum of exercises follows the topics of lectures of this course.

Laboratory Exercises of Process Control (2h/week, 4th semester) LMS Moodle. Matlab. Simulink. Laplace transform. Transfer function and transfer functions of complex systems. Step responses. Poles and zeros. Modelling of tanks. Modelling of heat exchangers. Feed-back control loop. Reference tracking and disturbance rejection. Control of tanks. Control of heat exchangers.

Programming I (2h/week, 4th semester) The curriculum of exercises follows the topics of lectures of this course.

Semestral Project I (3h/week, 4th semester) The main aim of the course is to become familiar with solution and management of projects and to train creativity and self-activity.

Web Technologies in Automation (2h/week, 4th semester) Introduction to Web Technologies. JavaScript I. JavaScript II. Synchronous and asynchronous communication. HTTP MATLAB Web Server. Virtual monitoring of laboratory processes. Virtual control of laboratory processes. Remote monitoring of laboratory processes. Remote control of laboratory processes. Industrial implementation of remote control. Final projects realization I. Final projects realization II. Projects presentation.

Design of Information and Control Systems (3h/week, 5th semester) The curriculum of exercises follows the topics of lectures of this course.

Introduction to XML Technologies (1h/week, 5th semester) The curriculum of exercises follows the topics of lectures of this course.

Optimization (2h/week, 5th semester) The curriculum of exercises follows the topics of lectures of this course.

Semestral Project II (3h/week, 5th semester) The main aim of the course is to become familiar with solution and management of projects and to train creativity and self-activity.

Bachelor Thesis (10h/week, 6th semester) The students can creatively solve problems related to the specified topic. They can do literature search and read and understand the available technical literature in Slovak and English. They are able to apply the knowledge acquired during their studies. They can plan and execute experiments. They are able to evaluate the achievements and make conclusions. They can prepare a written documentation of solving the problem and the results obtained. The students are able to defend their results.

Integrated Control in Process Industries (3h/week, 6th semester) The curriculum of exercises follows the topics of lectures of this course.

Programming II (2h/week, 6th semester) The curriculum of exercises follows the topics of lectures of this course.

Remote Control of Embedded Systems (2h/week, 6th semester) Embedded systems: Repetition – general introduction, characterization, usage in practice; sensors and actuators; microcontrollers. Programming methods for microcontrollers: Recapitulation. Introduction to Web-based communication technologies – HTTP and structures of transferred data (XML, SOAP, JSON), software for emulation of Web services, most commonly used communication scenarios. Methods of communication with control systems – data acquisition from control system, sending data to control system and their processing. Network communication – connection of wired network module to microcontroller, programming of network communication. Wireless Network – connection of wireless networking module to microcontroller, programming of network communication. Connection of control system to the Internet. Remote control of embedded systems via Web Interface – creation of simple Web application for communication with microcontrollers, visualization of process data, process control via Internet. Realization of final project. Presentation of final project.

5.4.3 Lectures in Master Study

Automatic Control Theory I (2h/week, 1st semester) Linear dynamical systems. State-space process models. Transfer functions of systems. Time response of linear systems. Frequency analysis. Continuous-time control. State controller and observer. Structure of state feedback.

Control of Technological Processes (1h/week, 1st semester) The students have become familiar with basic principles of identification from aperiodic or periodic step responses. The know principles of feed-back and feed-forward control. They know principles of process control using complex control structures. They know principles of control using simple and complex control structures that are implemented for control of selected processes from the chemical industry.

Modelling in Process Industry (2h/week, 1st semester) Introduction to modelling in process engineering, modelling of processes with discretely and continuously distributed parameters: tubular heat exchangers, tray distillation columns, packed distillation columns, packed absorption columns; modelling

of extractors without and with chemical reactions; modelling of tubular chemical reactors without and with catalyst; modelling of batch and semi-batch processes: chemical reactors, extractors and distillation columns.

Object Oriented Programming (1h/week, 1st semester) Terms, cycles, functions, directives, foundations of structure use, simple matched lists, classes and methods of classes, inheritance and polymorphism.

Process Dynamics and Control (2h/week, 1st semester) Feedback and feed-forward control. Complex control structures: cascade control, complex control structure with disturbance measurement, complex control structure with auxiliary control input, time-delay compensator – Smith predictor and its modifications, ratio control, advanced control methods. Process control: control of tanks, control of mixing units, control of heat exchangers, control of distillation columns, control of chemical reactors, control of dryers.

Programming of Web Application (1h/week, 1st semester) Repetition of XHTML and CSS languages, creation of static web pages, mastering and advanced work with PHP language, creation of custom functions, introduction to databases, SQL databases, MySQL database.

Technical Means of Automation (2h/week, 1st semester) Introduction to the course - Presentation of course's topics. Fundamentals of electricity and electric signals Sensors - measurement of process quantities. Static and dynamic characteristics of sensors. Temperature sensors. Pressure sensors. RC circuits and noise filters. Measurement of mechanics and physical properties of fluids. Actuators - control of technological processes. DC motors. AC motors. Valves and pumps. Industrial control systems. Introduction to digital control systems. Programmable logic controllers (PLC). PLC programming, ladder logic and ladder diagrams. Program organization in PLC. Industrial networks. Digital implementation of control.

Automatic Control Theory II (2h/week, 2nd semester) Discrete-time control. Z-transform. Discrete-time dynamic systems. Properties of discrete-time dynamic systems. Control design for discrete-time systems. Optimal Control. Optimisation and optimal control. Calculus of variations. Pontryagin's principle of minimum. Dynamic programming. Optimal state observers.

Identification (2h/week, 2nd semester) Introduction to identification, basic terms, subject of system identification. Identification procedure, structure selection, verification, input signals. Step responses, 1st order model. Step responses, 2nd order model. Step responses, higher order models. Autotuning. Frequency analysis, construction of frequency responses, estimation of transfer functions. Regression methods, estimation of parameters, identification of static models. Regression methods, identification of dynamic models. Recursive least squares, model identifiability, modifications of RLS. Recursive LS, continuous-time models. Models of linear dynamical systems, model verification. Practical issues in identification.

Informatization, Digitalization and Documentation of Heritage (1h/week, 2nd semester) The course is divided into four parts. The first one covers structure of XML documents and their syntax, tree organization of XML files and industrial standards derived from XML. Second part is devoted to validation of content of XML documents using DTD and XML Schema. Third part is concerned with the XPATH technology which allows to search through XML files. The final part deals with transformation of XML documents using XSLT.

Informatization Engineering and Systems I (1h/week, 2nd semester) The course is divided into two parts. The first one deals with the FOXBORO industrial control platform. This part of lectures is devoted to explaining specific aspects of this platform with respect to implementation of control algorithms and creation of graphical user interfaces. Second part, concerned with the SIMATIC platform, which includes overview of ladder logic, implementation of logic and PID control, creation of graphical user interface and their implementation on touch panels.

Matlab - Advanced Techniques (1h/week, 2nd semester) Introduction to MATLAB. Basic of MATLAB architecture Functions. Functions for working with data. Symbolic toolbox. Introduction to Object-Oriented Programming. Graphics objects GUIDE – graphical user interface. Low-level input and output. HTTP MATLAB Web Server I. HTTP MATLAB Web Server II

Automatic Control Theory III (2h/week, 3rd semester) Adaptive control (heuristic, self-tuning, MRAC). Multivariable control (RGA analysis, decoupling control, MPC). Process control (heat exchangers, distillation columns, chemical reactors, combustion, waste-water treatment plants).

Informatization Engineering and Systems II (2h/week, 3rd semester) The course is divided into four parts. The first one covers structure of XML documents and their syntax, tree organization of XML files and industrial standards derived from XML. Second part is devoted to validation of content of XML documents using DTD and XML Schema. Third part is concerned with the XPATH technology which allows to search through XML files. The final part deals with transformation of XML documents using XSLT.

Optimization of Processes and Plants (2h/week, 3rd semester) The main aim of this course is to give basic knowledge about optimization of processes and plants. Process (Plant) optimization is the discipline of adjusting a process (plant) so as to optimize some specified set of parameters. The most common goals are minimizing cost, maximizing throughput, and/or efficiency.

Intelligent Control (1h/week, 4th semester) Students know to apply artificial intelligence methods (methods of patterns recognition, problem solving, expert systems, fuzzy logic, fuzzy modelling and control, artificial neural networks, evolutionary algorithms) to solve problems in the identification, modelling and control of technological processes.

Predictive Control (1h/week, 4th semester) The course is divided into three main parts. The first one introduces the concept of model predictive control (MPC) and shows its analogies to optimal control. Second part describes mathematical fundaments required to formulate MPC problems as convex optimization problems. The final part discusses various formulations of MPC, including regulation towards non-zero references, removal of regulation offsets, and output regulation.

Robust Control (1h/week, 4th semester) Introduction to robust control. Systems with single parameter uncertainty. Systems with interval parametric uncertainty. Robust controller design for systems with interval uncertainty. Systems with linear affine uncertainty. Stability of Polytopic systems. Multilinear uncertainty. Generalized Kharitonov theorem. LMI in robust control. Robust pole-placement method. Introduction to unstructured uncertainty. Unstructured uncertainty – analysis and synthesis.

5.4.4 Laboratory Exercises in Master Study

Automatic Control Theory I (3h/week, 1st semester) The curriculum of exercises follows the topics of lectures of this course.

Control of Technological Processes (1h/week, 1st semester) The curriculum of exercises follows the topics of lectures of this course.

Industrial Control Systems (2h/week, 1st semester) Logical control and its implementation in Stateflow. Introduction to logical control and Stateflow. Sequence and state diagrams. Parallel state diagrams. Logical control for programmable logic controllers. Programmable logical controllers and ladder logic. Timers, counters and set-reset blocks. Working with memory mathematical expressions. Implementation of state diagrams.

Information Technology I (2h/week, 1st semester) Introduction to relational databases. Database system MS Access – overview of IDE. Database normalization (normal forms – 1NF, 2NF, 3NF). Table creation (fields, data types, indexes, field properties, update). Relations and reference integrity. Techniques for databases (E-R model). Forms and their elements. Forms and their data. Queries. SQL language I. SQL language II. Reports. Practical application using AIS database.

Modelling in Process Industry (2h/week, 1st semester) The curriculum of exercises follows the topics of lectures of this course.

Object Oriented Programming (3h/week, 1st semester) The curriculum of exercises follows the topics of lectures of this course.

Process Dynamics and Control (1h/week, 1st semester) The curriculum of exercises follows the topics of lectures of this course.

Programming of Web Application (2h/week, 1st semester) The curriculum of exercises follows the topics of lectures of this course.

Semestral Project I (4h/week, 1st semester) The students have become systematic knowledge of the issues studied and have become familiar with the

current state of the field related to the topic of the dissertation thesis. The students are able to classify the different approaches, analyse possibilities of the application and development of these approaches and critically evaluate their advantages and disadvantages. They are able to propose possible solutions and initial experiments focusing on the future thesis. They can conduct initial experiments and evaluated them.

Technical Means of Automation (2h/week, 1st semester) The curriculum of exercises follows the topics of lectures of this course.

Automatic Control Theory II (3h/week, 2nd semester) The curriculum of exercises follows the topics of lectures of this course.

Identification (2h/week, 2nd semester) The curriculum of exercises follows the topics of lectures of this course.

Informatization Engineering and Systems I (3h/week, 2nd semester) The curriculum of exercises follows the topics of lectures of this course.

Informatization, Digitalization and Documentation of Heritage (2h/week, 2nd semester) The curriculum of exercises follows the topics of lectures of this course.

Matlab - Advanced Techniques (1h/week, 2nd semester) The curriculum of exercises follows the topics of lectures of this course.

Professional Training (120h/semester, 2nd semester) Students are able to apply in practice their theoretical and methodological knowledge obtained during university studies. They have validated their knowledge and professional orientation. Students know possibilities of their work in practice.

Semestral Project II (4h/week, 2nd semester) The students have become systematic knowledge of the issues studied and have become familiar with the current state of the field related to the topic of the project. The students are able to define problems, to choose methods for solving them. The students are able to evaluate the possibility to implement and to develop chosen methods. The students are able to evaluate critically the advantages and disadvantages

of the chosen methods. They are able to propose possible solutions and experiments focusing on the future thesis. They can conduct initial experiments and evaluated them.

Automatic Control Theory III (2h/week, 3rd semester) The curriculum of exercises follows the topics of lectures of this course.

Creation of Scientific Documents (2h/week, 3rd semester) Student has knowledge how to create scientific documents with both WYSIWYG and transformation methods. He/she is able to work with bibliographic information, correctly cite various sources. Students can work with typesetting tool LaTeX, can generate in batch different presentation and print outputs. He/she also has knowledge about structured text systems as XML or DocBook.

Information Technologies II (2h/week, 3rd semester) Static and dynamic web pages and technologies – HTML and XHTML, structure of XHTML document (head and body). XHTML: text, links, ordered and unordered lists, images, tables. CSS: introduction, colour, font, justification, links, numbered and unnumbered lists, frames, borders, background, classes and identifiers. Apache HTTP server: installation and configuration. PHP: introduction, basic functions, HTML code generation, variables and their types, global variables, arrays, constants, conditions, loops, forms (methods, form elements, attributes), form data treatment. Introduction to databases: database, table, relation. Concept and architecture of databases and tables. Databases: design (tables, indexes, ...), editation. Introduction to PHP and MySQL. PHP and MySQL: development of web applications.

Informatization Engineering and Systems II (2h/week, 3rd semester) The curriculum of exercises follows the topics of lectures of this course.

Network Fundamentals (2h/week, 3rd semester) The focus of this course is on learning the fundamentals of networking. Students will learn both the practical and conceptual skills that build the foundation for understanding basic networking. They will be introduced to the two major models used to plan and implement networks: OSI and TCP/IP. They will become familiar with the various network devices, network addressing schemes , types of media used to carry data across the network, LAN/ WAN technologies and protocols, security and the wireless. This course also introduce to understand of how

Internet works, how a router learns about remote networks (static and dynamic routing) and how the switch communicates with other switches and routers in the network to implement VLAN segmentation.

Optimization of Processes and Plants (2h/week, 3rd semester) The curriculum of exercises follows the topics of lectures of this course.

Process Control Project (3h/week, 3rd semester) Project represents individual student work to solve control of laboratory processes in chemical and biochemical technologies. Student has to combine knowledge from various subjects in engineering study. He studies a selected laboratory process, designs and simulates its behaviour and verifies at the actual plant. In conclusions, forms results and presents them.

Project Software Systems (2h/week, 3rd semester) Introduction to version management, examples from practice, centralized vs. decentralized access, CVS, SVN, git and Mercurial, graphical user interfaces.

Semestral Project III (4h/week, 3rd semester) The students have become deep systematic knowledge of the issues studied and have become familiar with the current state of the field related to the topic of the project. The students are able to define problems, to choose methods for solving them. The students are able to evaluate the possibility to implement and to develop chosen methods. The students are able to evaluate critically the advantages and disadvantages of the chosen methods. They are able to propose possible theoretical solutions and experiments needed for the confirmation of solvability of defined problems.

Diploma Project (20h/week, 4th semester) The students can creatively solve problems related to the specified topic. They can do literature search and read, understand and use available technical literary sources in Slovak and English. The students are able to apply the knowledge acquired during their studies. They can plan and execute experiments. They are able to evaluate critically the achieved results and make conclusions. They have learned to create a written documentation of their work. The students are able to defend their results.

Intelligent Control (2h/week, 4th semester) The curriculum of exercises follows the topics of lectures of this course.

Predictive Control (2h/week, 4th semester) The curriculum of exercises follows the topics of lectures of this course.

Robust Control (2h/week, 4th semester) The curriculum of exercises follows the topics of lectures of this course.

6 Current Research Activities

Research at the Department of Process Control orients to advanced control theory and modelling of chemical and biochemical processes. Current research areas, among other research fields, include optimization, model predictive control, robust control, etc. Previously members of the department focused also on adaptive control and identification.

6.1 Main Research Areas

Modeling and Simulation (M. Bakošová, P. Valiauga) Modelling and simulation play an important role in the investigation of static and dynamic properties of chemical processes, units and systems. Most chemical systems are strongly non-linear and their simulation is necessary for the control design as well as for the investigation of the overall control systems. The main aim of the research is to develop program packages for modelling and simulation of various kinds of models. During the last year a package MODELTOOL for MATLAB/ Simulink was improved and its Internet module was created. Also, Honeywell's UniSim Design Suite is an intuitive process modelling software that helps engineers create steady-state and dynamic models for plant design, performance monitoring, troubleshooting, business planning and asset management.

Neural Networks and Fuzzy Control (A. Mészáros, A. Vasičkaninová) The aim of this research is to investigate fuzzy controllers based on genetic algorithms, two-layer hierarchical control structures for biochemical systems, integrated optimizing algorithms for higher layers of hierarchical control structures, artificial neural-network models obtained by back-propagation for specified biochemical systems, design of a robust long-range constrained predictive control algorithms on the basis of ANN involving a stochastic approximation training algorithm, and development of a control system for our laboratory fermenter.

Model Predictive Control (M. Kvasnica, M. Klaučo, P. Bakaráč, M. Furka, M. Horváthová) Model Predictive Control (MPC) is widely studied advanced control strategy in roots in Dynamic Matrix Control. The focus in this research domain is divided into two main areas, the first being the online MPC and the second is the explicit MPC. Theoretical and practical aspects of the MPC strategy are studied. The online MPC discipline covers design and

implementation of MPC strategies based on linear, quadratic and mixed-integer programming. The second area includes parametric programming and development of Multi-Parametric Toolbox[1].

Dynamic Optimisation (M. Fikar, R. Paulen, M. Mojto) Increased quality requirements in chemical and petrochemical industries call for more complicated and sophisticated control strategies. Moreover, there is a need to know the achievable limits of performance and speed of transient behavior of processes. Optimal control theory is able to provide responses to these questions. We study membrane processes, multicomponent distillation, waste-water treatment, etc.

Robust Control (M. Bakošová, J. Oravec, A. Vasičkaninová, P. Valiauga, M. Horváthová) Research is focused to design the robust control and robust model predictive control of the system in the presence of the uncertain parameters. The investigated systems are the processes of the chemical and food technology, such as chemical reactors, heat exchangers and the others. From the control viewpoint the main demands are the stability issues, control performance, the optimization of energy resources, and a overall computational burden. The designed robust control is validated using the simulation of control and the real laboratory processes.

Control Engineering Education (M. Fikar, Ľ. Čirka, M. Bakošová, M. Kalúz, J. Oravec, R. Valo) Research in this domain focuses on application of information technologies in control education. This covers interactive on-line blocks, automatic generation of testing problems, development of educational process plants.

Information Technologies (M. Fikar, Ľ. Čirka, M. Kvasnica, M. Kalúz) Research in this domain is oriented to:

- application of information technologies for data treatment and visualisation
- development of static and dynamic web pages not only for purposes of measurement and control but for general information treatment
- automatic data acquisition from various Internet sources

[1] M. Herceg, M. Kvasnica, C.N. Jones, and M. Morari. Multi-Parametric Toolbox 3.0. In Proc. of the European Control Conference, pages 502–510, Zurich, Switzerland, July 17–19 2013. http://people.ee.ethz.ch/~mpt/3/

Open Source solutions are applied: web, mail, smb servers, databases (MySQL), programming tools (PHP, JavaScript) on operating systems FreeBSD, GNU Linux, Solaris.

Machine Learning in Process Control (M. Kvasnica, M. Klaučo, M. Kalúz, K. Kiš) Machine learning is attracting huge interest not only in academia but also in the industry. The primary aim of this research is to study the application of machine learning approaches to enhance and design controllers of various nature and structure.

Guaranteed Parameter Estimation (R. Paulen, P. Valiauga, C. E. Valero) The quality of the results of model-based optimization and control strongly depends on the accuracy of the models employed. It is essential that the predictions of variables that are considered in the optimization problem, e.g. product quality parameters, are accurate. The quality of the models can be improved by online adaptation of crucial parameters via robust state and parameter estimation schemes. In this respect, we pursue a guaranteed parameter estimation approach to obtain robust estimates of uncertain parameters while avoiding unreliable approximations that are associated with classical estimation approaches.

6.2 International Scientific Projects

6.2.1 New Directions in Guaranteed Estimation of Nonlinear Dynamic Systems and Their Applications to Chemical Engineering Problems (M. Fikar, R. Paulen)

Period: 2018 – 2020

Financing: European Commission – H2020, MSCA-IF-EF-ST

The technique of guaranteed estimation promises a revolutionary step to how industrial process managers build, handle and adapt the prediction mathematical models. These are used to monitor the equipment operating regimes, to train the operating personnel and are also exploited to steer the plants' behavior towards the most profitable or the most resource- efficient modes. Advantages of guaranteed estimation come from the fact that no unnecessary assumptions must be made regarding the quality and measurement-error distribution of the sensed data, which establishes an increased reliability of the obtained estimation results. The work on this project develops the essential parts of guaranteed estimation techniques for real-world exploitation. We

focus on the estimation of parameters of the nonlinear dynamic models while combining the estimation with model validation principles and while creating a hybrid estimation technique that enjoys the advantages of both guaranteed estimation and conventional approaches. In order to drive the operation of the plant, here we focus on the plants of chemical industry, to an efficient working regime, the technology of optimal and robust control is required. Our project builds upon the developments of robust control and develops novel optimal robust control techniques that incorporate the information on guaranteed estimates into the actions, i.e. manipulations of the plants' degrees of freedom. As a result, a safe, reliable and resource-efficient operation is established. The theoretical developments of the project are implemented into a software package and released as an open-source project such that the collaboration with academia and industrial stakeholders is fostered. A demonstration on a pilot plant is also planned to showcase the benefits of developed techniques in the real-world environment. A sound dissemination plan of the project ensures that the project reaches its target audience.

6.2.2 Embedded Optimal Control (M. Fikar)

Period: 2017 – 2020

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (research group of M. Fikar)
- Ruhr-Universität Bochum, Department of Automatic Control and Systems Theory, Faculty of Mechanical Engineering (research group of M. Mönnigmann)

The aim of the project supported by the Alexander von Humboldt Foundation is to establish research cooperation between the group of prof. M. Fikar, DrSc at Institute of Information Technology, Automation and Mathematics, Faculty of Food and Chemical Technology of the Slovak University of Technology (STU) in Bratislava (Slovakia) and the group of prof. Dr. M. Mönnigmann at Department of Automatic Control and Systems Theory, Faculty of Mechanical Engineering of the Ruhr-Universität Bochum (RUB). The cooperation will be focused on optimal model-based control and optimisation primarily targeted at embedded control systems. The group at STU is particularly strong at geometric techniques in explicit model predictive control (MPC) and in software development whereas the group at RUB excells in complexity reduction

techniques of both explicit and on-line MPC. The main research idea of the project is to take advantage of the interdisciplinary communication and collaboration between specialists from both groups, foster new cooperation activities, and common European research projects. The project includes short-term visits mainly of young scientists from both groups, organisation as well as participation in conferences and lectures at partner groups.

6.2.3 Reliable and Real-time Feasible Estimation and Control of Chemical Plants (R. Paulen)

Period: 2018 – 2019

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (R. Paulen, J. Oravec)
- Technische Universität Dortmund (research group of S. Engell)

The goal of this project is to bring together scientists who share common research interests in the development and application of advanced estimation and control algorithms for dynamic systems in order to achieve greater energy and material efficiency as well as safety of chemical production sites. The scientific goals of the cooperation are to develop a methodology for efficient guaranteed parameter and state estimation of nonlinear dynamic systems, which shall be integrated with advanced optimizing-control schemes. Software implementations will be delivered and will be made freely available as a part of this project. Moreover, this project aims at the demonstration of the developed tools by applying them to laboratory chemical process systems, a pilot membrane filtration system, a distillation column and a chemical reactor.

6.2.4 APVV SK-CN-2015-0016: Verified Estimation and Control of Chemical Processes (R. Paulen)

Period: 2018 – 2019

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (R. Paulen, M. Kvasnica, J. Oravec, M. Fikar)
- ShanghaiTech University (research group of B. Houska)

The goal of this project is to bring together scientists who share common research interests in the development and application of verified estimation and control algorithms for dynamic systems in order to achieve greater energy- and material efficiency as well as safety of chemical production sites. The research team consists of students and professors with backgrounds in mathematics, control and engineering. The scientific goals of the cooperation are to develop a methodology for efficient guaranteed parameter and state estimation of nonlinear dynamic systems, which shall be synthesized with advanced model predictive control schemes. Software implementations will be delivered as part of this project. Moreover, this project aims at a demonstration of the developed tools by applying them to laboratory chemical process systems, membrane filtration system and distillation column.

6.3 Research Projects in Slovak Republic

6.3.1 VEGA 1/0112/16: Control of Energy Intensive Processes with Uncertainties in Chemical Technologies and Biotechnologies (M. Bakošová)

Period: 2016 – 2019

The research project deals with the development of advanced control methods for systems with uncertainties and focuses on energyintensive processes in the chemical and biotechnologies such as distillation columns, chemical reactors, biochemical reactors, heat exchangers and other processes. The core of the project consists of development of robust predictive control and fuzzy robust control approaches for systems with uncertainties to ensure the control of processes leading to energy savings compared with traditional approaches. Computational effectiveness and usability in practice will be taken into account in the design of control algorithms for systems with uncertainties. Designed algorithms, controllers and control structures will be tested by simulations and laboratory experiments and will be compared with classical control approaches from the viewpoint of energy consumption during the control.

6.3.2 VEGA 1/0004/17: Energy Efficient Process Control (M. Fikar)

Period: 2017 – 2020

The scientific project focuses on design of process control in chemical and food technologies. The main aim is to stress efficiency and optimality from the energy usage point of view. We will mainly investigate two types of processes:

membrane filtration and heat transfer processes. Membrane processes will be studied both theoretically and practically for energy consumption reduction and design of optimal operation. As far as heat transfer processes are concerned, we will treat heat-exchanger networks and energetically optimal control of distillation columns.

Theoretical aspects of the project will use techniques of optimal and predictive control as well as self-optimising control structures that make possible to control processes close to optimal regime without any computationally demanding online optimising strategies. The aim of the project is to design such procedures that will be usable for minimisation of energy in steady-states for continuous-type of processes as well as in transient situations for batch processes.

The obtained results will be published at important scientific conferences and in journals with a high impact factor. Also, they will be implemented in software open-source packages available in Internet.

6.3.3 VEGA 1/0585/19: On-Line Tunable Explicit Model Predictive Control for Systems with a Fast Dynamics (M. Kvasnica)

Period: 2019 – 2022

The aim of the project is the development of a unified methodology for the design, synthesis, and implementation of explicit model predictive controllers that can be tuned on-line by changing the parameters of the cost function and/or of the prediction model. Explicit predictive controllers are known to combine quality and safety of nonlinear control algorithms with the cheap implementation complexity known from linear controllers. Therefore they allow for an optimal and safe regulation of systems with a fast dynamics with time constants in the order of milli- to micro-seconds. Their main drawback, however, is that they cannot be re-tuned on-line. Mitigation of this drawback will lead to extension of the current knowledge in the areas of optimal and predictive control and, more importantly, will enable such controllers to be employed in process automation where quality and safety of control algorithms is of paramount importance.

6.3.4 APVV-15-0007: Optimal Control for Process Industries (M. Fikar)

Period: 2016 – 2020

The main aim of the project is design of effective and advances methods of process control and study of optimal process operation. We will aim our attention mainly to processes with heat and mass transfer. These processes

are inherently complex, exhibit nonlinearities and hybrid behaviour that has consequences in control quality and performance. Optimal control will include dynamic optimisation in continuous and discrete domains as a tool for qualitative analysis at upper process control level. Repeated dynamic optimisation at the lower lever yields algorithms of predictive control. This will result in characterisation of optimal operation regimes and controllers optimising processes and large units composed from them. Also important will be software implementation of proposed solutions, available to a larger community in open source code as well as verification in laboratory conditions.

6.3.5 Machine Learning and Artificial Intelligence in Process Control and Automation (M. Kvasnica)

Period: 2017 – 2019

The aim of the project is to apply machine learning and artificial intelligence methods to synthesize control systems composed of three components: an inference mechanism, a process model, and a control strategy. The task of the inference mechanism is to deduce values of unmeasured parameters and process values from known measured signals. Subsequently, the inferred values are utilized by the process model to predict the future evolution of the controlled plant. Finally, the aim of the control strategy is to deduce optimal control actions based on the process model. The implementation of these blocks will be based on, respectively, machine learning techniques (SVM, PCA, etc.), deep neural networks, and model predictive control. The objective of the project is to extend existing machine learning and artificial intelligence techniques to systems that combine continuous dynamics with discrete logic (known as hybrid systems), to combine the methods in a systematic manner, and to implement developed algorithms in the form of open-source software packages.

6.3.6 Economically Effective Control of Energy Intensive Chemical Processes (M. Klaučo)

Period: 2018 – 2019

This project deals with designing of advanced model predictive control synthesis for energy-demanding chemical processes. Especially in these type of process, the choice of a suitable control strategy is largely affecting the economic aspects of production. The main of such control strategy is to minimize the input raw materials and decrease the maintenance costs. Into the family of energy-demanding chemical, processes belong, for example, the distillation column or

steam-gas powerhouses. In these types of processes, even a small reduction of input raw materials has the a huge economic impact. In this project, we will present a synthesis of an advanced model predictive controller which the main purpose will be to optimize setpoints for current control algorithms. This type of control strategy is called "MPC-based Reference Governor Control". By implementing this kind of controller, we will avoid upgrading current control strategies, which is often costly process. Furthermore, since the advanced MPC controller is an optimization-based control strategy, the use of such strategy naturally leads to optimal plant behavior.

6.3.7 Development and Design of Smart Sensors for Chemical Industry (P. Bakaráč)

Period: 2019 – 2019

The methods of receiving measured data, accuracy, reliability, robustness and other properties of sensors have the key role in the control of chemical-technological processes. Increased quality and accuracy of measured controlled variables can improve the efficiency of the control from the time and energy point of view. Many times even small progress in the effectiveness of the control of the real chemical-technological unit can save costs (thousands or hundreds of thousands of euros). The next step of technological development of industrial sensors are so called smart sensors. The goal of this project is to develop two smart sensors for the measurement of the temperature and concentration of a gas. These sensors will be implemented into the educational laboratory processes located in the labs. The purpose of these smart sensors will be to increase the efficiency of the control algorithms.

6.3.8 STU as the Leader of Digital Coalition (M. Klaučo)

Period: 2019 – 2019

Team members: M. Bakošová, M. Kvasnica, R. Paulen, P. Bakaráč, M. Kalúz, M. Klaučo

The main goal is to support of universities in fulfilling the commitments made within the National Coalition for Digital Skills and Jobs of SR. Our first strategic goal is to create prerequisites for the regeneration of teaching and research staff by the healthy qualification growth of own talents. We want to stimulate the development and creativity in the whole range of scientific and professional career growth. We also want to create prerequisites and conditions for the smooth including of the teachers into the research projects.

7 Cooperations

7.1 International Cooperations

- Department of Process Control and Computer Techniques, Faculty of Chemical Technology, University of Pardubice, Pardubice, Czech Republic (Control system design)
- Department of Computing and Control Engineering, Prague Institute of Chemical Technology, Prague, Czech Republic (Control system design)
- Faculty of Applied Informatics, Tomas Bata University, Zlín, Czech Republic (Adaptive control, robust control)
- Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic, Prague, Czech Republic (Polynomial synthesis, Model Predictive Control)
- Faculty of Electrical Engineering, Czech Technical University, Prague, Czech Republic (Model Predictive Control)
- LSGP-CNRS, Ecole Nationale Superieure des Industries Chimiques (ENSIC), Nancy, France (Dynamic optimisation and control)
- Ecole Nationale Superieure des Ingénieurs de Génie Chimique-Chemin de la Loge, Toulouse, France (Neural networks, Learning automata, Model Predictive Control)
- Automatic Control Laboratory, ETH Zurich, Switzerland (Model Predictive Control, Modeling, analysis, and control of hybrid systems)
- University of Bochum, Bochum, Germany (Closed-loop identification, Model Predictive Control)
- University of Dortmund, Dortmund, Germany (Model Predictive Control)
- Technical University of Budapest, Budapest, Hungary (Modelling of chemical processes)
- University of Veszprem, Hungary (Environmental engineering, Bioengineering projects)
- TU Wien, Austria (Institute of Mechanics and Mechatronics)
- Imperial College London, London, United Kingdom (Global optimization, Parameter estimation)

7.2 Cooperations in Slovakia

- Institute of Control and Industrial Informatics, Faculty of Electrical Engineering and Informatics, Slovak University of Technology in Bratislava
- Institute of Automation, Measurement, and Applied Informatics, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava

- Institute of Informatics, Slovak Academy of Sciences, Bratislava
- Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Košice
- Institute of Control and Informatization of Production Processes, BERG Faculty, Technical University of Košice, Košice
- ProCS s.r.o, Actemium Slovakia, Šaľa
- Slovnaft, Inc., Bratislava
- NCHZ, Inc., Nováky
- Regotrans-Rittmeyer Slovakia s.r.o., Bratislava
- Fuzzy, s.r.o., Diakovce

7.3 Membership in International Organizations and Societies

- International Federation of Automatic Control, Laxenburg, Austria (M. Fikar, M. Klaučo, R. Paulen)
- European Federation of Biotechnology, Brussels, Belgium (A. Mészáros)
- New York Academy of Sciences, New York, USA (A. Mészáros)
- European Control Association (M. Kvasnica)
- IEEE (M. Fikar)
- European Federation of Chemical Engineers, working party on CAPE (M. Fikar, A. Mészáros)

7.4 Membership in Domestic Organizations and Societies

- Slovak Society for Cybernetics and Informatics (A. Mészáros, J. Mikleš)
- Slovak Society of Chemical Engineering (M. Bakošová, M. Fikar, J. Mikleš, A. Mészáros)
- Slovak Society of Industrial Chemistry (M. Bakošová, L. Čirka, M. Fikar, A. Mészáros, J. Mikleš, A. Vasičkaninová)

8 Theses and Dissertations

8.1 Bachelor Theses (BSc. degree)

for state examinations after three years of study (supervisors are written in parentheses)

M. Gubrický	Control of Oscillatory Systems (Klaučo, M.)
M. Hatvanyi	MIMO Control of a Chemical Reactor (Klaučo, M.)
K. Karaffová	Indoor Navigation System for Robotic Vehicles (Kalúz, M.)
J. Kavor	Modelling and Contol of a Cascade of Biochemical Reactors for the Removal of Nitrogen Compounds from Wastewater (Bakošová, M.)
D. Križan	Modelling and Control of a Cascade of Biochemical Reactors for the Removal of Organic Pollutants from Waste Water (Bakošová, M.)
T. Kyselica	Modelling and Control of a Biotechnological Reactor for the Production of Ethanol (Bakošová, M.)
M. Lehotová	Modelling and Control of a Fermentation Reactor (Bakošová, M.)
L. Míková	Model predictive control design for the laboratory chemical reactor (Oravec, J.)
J. Štofa	Developement and control of mechatronic process (Kalúz, M.)
A. Žabková	Optimal Operation of a Membrane Process (Paulen, R.)

8.2 Master Theses (MSc. degree)

for state examinations after five years of study (supervisors are written in parentheses)

D. Boroš	Methods of bi-level optimization (Paulen, R.)

O. Čizmazia	Design of Control System for Pasteurization Process (Kalúz, M.)
M. Furka	Development of Control Algorithms for Rotational Inverted Pendulum (Klaučo, M.)
M. Horváthová	Convex-lifting-based robust control design (Oravec, J.)
R. Hronec	Control of a Position of an Object in Air Flow (Klaučo, M.)
K. Kiš	Machine Learning Approaches Applied to Generation of Explicit Control Laws (Klaučo, M.)
M. Malovcová	Electronic System for Property Records using Barcodes and QR Codes (Kalúz, M.)
M. Mojto	Advanced Process Control of a Depropanizer Column (Fikar, M.)
J. Nosko	Data Statistical Analysis in R Language (Čirka, Ľ.)

9 Publications

9.1 Book

1. M. Klaučo – M. Kvasnica: *MPC-Based Reference Governors*, 2019.

9.2 Articles in Journals

1. P. Bakaráč – M. Kvasnica: Approximate explicit robust model predictive control of a CSTR with fast reactions (in). *Chemical papers*, pp. 611 – 618, 2019. doi: https://doi.org/10.1007/s11696-018-0630-4

2. M. Bakošová – J. Oravec – A. Vasičkaninová – A. Mészáros – P. Valiauga: Advanced Control of a Biochemical Reactor for Yeast Fermentation. *Chemical Engineering Transactions*, pp. 769 – 774, 2019. doi: https://doi.org/10.3303/CET1976129

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9.3 Articles in Conference Proceedings

1. M. Bakošová – R. Trautenberger – J. Derco – J. Kavor – P. Valiauga – J. Oravec – A. Vasičkaninová: Modelling and Control of a Carrousel Type Biochemical Reactor. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 22nd International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, 2019.

2. Ľ. Čirka – M. Kalúz – D. Dzurková – R. Valo: Educational Device Flexy2 in the Teaching of Experimental Identication. Editor(s): M. Fikar and

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3. W. Daosud – P. Kittisupakorn – M. Fikar – S. Lucia – R. Paulen: Efficient robust nonlinear model predictive control via approximate multi-stage programming: A neural networks based approach. Editor(s): Anton A. Kiss, Edwin Zondervan, Richard Lakerveld, Leyla Özkan, In *29th European Symposium on Computer Aided Process Engineering*, Elsevier, vol. 29, pp. 571 – 576, 2019. doi: https://doi.org/10.1016/B978-0-12-818634-3.50096-5

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5. M. Fikar: Optimal Control of Membrane Processes. In *Process Systems Engineering (PSE) Asia*, Chulalongkorn Unviersity, Bangkok, Thajsko, pp. 6 – 6, 2019.

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7. L. Galčíková – J. Oravec – M. Bakošová: Advanced Robust MPC Design for Plate Heat Exchanger. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 22nd International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, 2019.

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9. M. Kalúz – M. Klaučo – Ľ. Čirka – M. Fikar: Flexy2: A Portable Laboratory Device for Control Engineering Education. In *12th IFAC Symposium Advances in Control Education*, pp. 159 – 164, 2019.

10. K. Kiš – M. Klaučo: Machine Learning Approaches Applied to Generation of Explicit Control. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings*

of the 22nd International Conference on Process Control, Slovak Chemical Library, Štrbské Pleso, Slovakia, 2019.

11. M. Klaučo – M. Kvasnica: Parametric Optimization with the MPT Toolbox and its Applications in Optimal Control. In *30th European Conference on Operational Research*, Dublin, vol. 30, 2019.

12. Y. Lohr – M. Klaučo – M. Kalúz – M. Mönnigmann: Mimicking Predictive Control with Neural Networks in Domestic Heating Systems. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 22nd International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 19 – 24, 2019.

13. M. Mojto – K. Ľubušký – M. Fikar – R. Paulen: Design of Data-based Inferential Sensors for Industrial Depropanizer Column. Editor(s): G. Léonard and F. Logist, In *Computer Aided Process Engineering, CAPE Forum*, pp. 12 – 13, 2019.

14. M. Mojto – K. Ľubušký – R. Paulen – M. Fikar: Advanced Process Control of a Depropanizer Column. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 22nd International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, 2019.

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16. J. Su – Y. Zha – K. Wang – M. Villanueva – R. Paulen – B. Houska: Interval Superposition Arithmetic for Guaranteed Parameter Estimation. In *12th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems DYCOPS 2019*, Elsevier, pp. 574 – 579, 2019. doi: https://doi.org/10.1016/j.ifacol.2019.06.124

17. S. Thangavel – S. Subramanian – R. Paulen – S. Engell: Robust Multi-Stage NMPC under Structural Plant-Model Mismatch without Full-State Measurements. In *European Control Conference 2019*, IEEE, pp. 781 – 786, 2019.

18. C. E. Valero – R. Paulen: Set-Theoretic State Estimation for Multi-output Systems using Block and Sequential Approaches. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 22nd International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 268 – 273, 2019.

19. C. E. Valero – R. Paulen: Effective Recursive Set-membership State Estimation for Robust Linear MPC. In *12th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems DYCOPS 2019*, Elsevier, pp. 486 – 491, 2019. doi: https://doi.org/10.1016/j.ifacol.2019.06.109

20. P. Valiauga – R. Paulen: Moving-horizon Guaranteed Parameter Estimation: Influence of the Measurement Error. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 22nd International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 256 – 261, 2019.

21. P. Valiauga – R. Paulen: Moving-horizon Guaranteed Parameter Estimation. In *12th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems DYCOPS 2019*, Elsevier, pp. 112 – 117, 2019. doi: https://doi.org/10.1016/j.ifacol.2019.06.046

22. A. Vasičkaninová – M. Bakošová – J. Oravec – A. Mészáros: Model Predictive Control of a Tubular Chemical Reactor. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 22nd International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 228 – 233, 2019.

23. M. Villanueva – X. Feng – R. Paulen – B. Chachuat – B. Houska: Convex Enclosures for Constrained Reachability Tubes (in). In *12th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems DYCOPS 2019*, Elsevier, pp. 118 – 123, 2019. doi: https://doi.org/10.1016/j.ifacol.2019.06.047

9.4 Patents

1. P. Bakaráč – M. Klaučo – J. Oravec: Electronic Sensoric Board (in Slovak). 2019.

10 International Visits

10.1 Visits to STU

Scientific Seminars

- 8.3.2019 A. Kugi — Mathematical Modeling and Advanced Process Control for Industrial Applications in the Steel Industry (TU Vienna, Austria)
- 29.3.2019 R. Mitze — Algebraic Dynamic Programming for Constrained Linear-Quadratic Optimal Control Problems (Ruhr University Bochum, Germany)
- 29.3.2019 D. Dillkötter — Model-Based Feedforward Control of the Laser Metal Deposition Process (Ruhr University Bochum, Germany)
- 21.5.2019 J. Drgoňa — Implementation and Remote Operation of White-Box Model Predictive Control in an Office Building (KU Leuven, Belgium)
- 1.7.2019 G. Sanchez — Technologies for Crop Monitoring – Some Opportunities and Challenges in India (JK Lakshmipat University, India)
- 16.7.2019 J. Czeczot, M. Fratczak, P. Nowak, P. Grelewicz — Model-Based Control in Industrial Automation - Implementation and Tuning (Silesian University of Technology, Poland)
- 26.8.2019 B. Houska — Moment Based Learning (ShanghaiTech University, China)
- 11.9.2019 A. W. Y. Shardt — Big Data and System Identification: Challenges and Opportunities (TU Ilmenau, Germany)
- 16.9.2019 K. Jastřembská — Pressure driven membrane processes: Membrane and its role in the separation (Univerzita Pardubice, Czechia)

10.2 Visits from STU

Participation at Conferences

• 13–16.1.2019	M. Fikar	Plenary lecture at the International Conference Process Systems Engineering Asia, in Bangkok, Thailand.
• 26–27.3.2019	R. Paulen, M. Mojto	Advanced Process Modelling (APM) Forum 2019 in London, UK.
• 23–26.4.2019	R. Paulen, C.E. Valero, P. Valiauga	IFAC Symposium on Dynamics and Control of Process Systems, in Florianopolis, Brazil.
• 16–19.6.2019	M. Fikar, R. Paulen	29th European Symposium on Computer–Aided Process Engineering, in Eindhoven, Netherlands.
• 7–9.7.2019	M. Kalúz, Ľ. Čirka	IFAC Symposium on Advances in Control Education, Philadelphia, USA.

Scientific Seminars

• 17.1.2019	P. Valiauga	Guaranteed Parameter Estimation (TU Dortmund, Germany)
• 17.1.2019	C.E. Valero	Effective Recursive Set–membership State Estimation for Robust Linear MPC (TU Dortmund, Germany)
• 6.2.2019	R. Paulen	Model-based design of optimal experiments using exact confidence regions (Imperial College London, UK)
• 24.2.2019	J. Oravec, M. Horváthová	Experimental Analysis of Advanced Controller Design Strategies (Shinshu Univeristy, Japan)
• 4.4.2019	P. Valiauga	Moving-horizon Guaranteed Parameter Estimation (ShanghaiTech University, China)
• 15.4.2019	R. Paulen	Effective recursive parallelotopic bounding for robust output-feedback control (KU Leuven, Belgium)

• 25.6.2019	R. Paulen	Optimal Control of Membrane Diafiltration Processes (Imperial College London, UK)
• 3.9.2019	R. Paulen	Optimal Control of Batch Membrane Processes (TU Dortmund, Germany)
• 9.9.2019	M. Mojto	Control Structure Analysis and Design of Inferentials for an Industrial Depropanizer Column (TU Dortmund, Germany)
• 18.10.2019	R. Paulen	Optimal operation of membrane processes (University of Chemistry and Technology, Prague and at University of Pardubice)

11 Miscellaneous

11.1 Awards

- Ing. P. Bakaráč
  - Dean's Praise for outstanding and fulfillment academic duties, results achieved in student scientific and professional activities.
- Ing. M. Furka
  - Dean's Praise for outstanding and fulfillment academic duties, results achieved in student scientific and professional activities.
- Ing. M. Horváthová
  - Dean's Praise for outstanding and fulfillment academic duties, results achieved in student scientific and professional activities.
- Ing. P. Valiauga
  - Student of the year 2019 at the Slovak University of Technology.
  - Dean's Praise for outstanding and fulfillment academic duties, results achieved in student scientific and professional activities.