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

2020

Address:

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

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Absent: J. Mikleš, C. E. Valero

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 process control design, implementation, and application of control systems. The educational pyramid includes a three year bachelor study in the study program called Information Engineering, Automation and Management in Chemical and Food Industry, a 2-year master study in the program Information Engineering and Automation in Chemical and Food Industry, and a four year doctoral study in the program Process Control.

Nowadays, information technologies and advanced process control systems represent vital 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 department's main branch of teaching and research activities is oriented towards process control, optimization-based control design, identification and modeling of dynamical systems, industrial automation, and the development of software packages for intelligent control systems. We also acknowledge recent trends that occur in scientific and industrial practice in incorporating knowledge about machine learning and data science in our research and teaching activities. 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 point out the zero unemployment rate of our graduates during our department's whole history. The department graduates do well in companies and institutions oriented on the design and installation of control systems for various technologies and in the fintech sector or as founders of their own companies.

As of September 2020, I was appointed by M. Kvasnica as the new head of the department. Together with my deputy R. Paulen, we will continue in close cooperation with our colleagues to increase the quality of both research and teaching domains.

Ing. MSc. Martin Klaučo, 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 2020.

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. Prof. Ing. Miroslav Fikar, DrSc. was head of the department in 2003 – 2019 and doc. Ing. Michal Kvasnica, PhD was head of department in 2019 – 2020. New head of the department is Ing. MSc. Martin Klaučo, 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	Bakaráč, Fedorová, Galčíková, Kohút
2nd semester (Summer)		
Information Engineering and Systems	1/2/0	Kalúz
Internet and Information Systems	0/0/2	Čirka
MATLAB - Advanced Techniques	1/0/1	Furka
Spreadsheet and Database Systems for Data Processing	0/0/2	Čirka
3rd semester (Winter)		
Fundamentals of Language C	0/0/2	Furka
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, Mojto
Laboratory Exercises of Process Control	0/0/2	Bakaráč, Horváthová, Vasičkaninová
Process Control	2/0/0	Oravec
Programming I	2/0/2	Kiš, Kvasnica
Web Technologies in Automation	0/0/2	Čirka
5th semester (Winter)		

Design of Information and Control Systems	2/0/3	Kalúz, Valo
Optimization	2/0/2	Horváthová, Kvasnica
6th semester (Summer)		
Integrated Control in Process Industries	2/0/3	Bakošová, Mészáros, Oravec, Vasičkaninová
Programming II	1/2/0	Kiš, 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, Paulen
Industrial Control Systems	0/0/2	Valo
Information Technology I	0/0/2	Mojto
Modelling in Process Industry	2/2/0	Bakošová, 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, Furka, Kalúz
2nd semester (Summer)		
Automatic Control Theory II	2/0/3	Fikar, Klaučo, Mojto
Identification	2/0/2	Čirka, Fikar
Informatization Engineering and Systems I	1/0/3	Kalúz, Valo
Matlab - Advanced Techniques	1/0/1	Furka

3rd semester (Winter)

Automatic Control Theory III	2/0/2	Fikar, Galčíková, Horváthová, Oravec
Creation of Scientific Documents	0/2/0	Mojto
Information Engineering and Systems II	2/0/2	Čirka
Optimisation of Processes and Plants	2/0/2	Fedorová, Klaučo, Kvasnica
Process Control Project	0/0/3	Kalúz, Klaučo
Project Software Systems	0/2/0	Oravec

4th semester (Summer)

Intelligent Control	1/2/0	Mészáros, Vasičkaninová
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	Mészáros
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 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. 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) 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, K. Fedorová, R. Kohút) 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, M. Horváthová, L. Galčíková) 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, M. Mojto, 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.

Distributed and Decentralized Optimization (M. Kvasnica, K. Fedorová, R. Kohút, K. Kiš) Research is focused on the control of the system in distributed and decentralized way, in order to decrease computational burden per calculation unit or increase privacy of each node in network. This approach can be also helpful to find the global optimum of non-convex optimization problems.

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 APVV DS-FR-19-0031: Full-Authority Vehicle Control Strategy (M. Klaučo)

Period: 2020 – 2022

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Information Engineering and Process Control (M. Klaučo, M. Kvasnica, K. Kiš)
- Czech Technical University, Faculty of Electrical Engineering, Department of Control Engineering (group of Dr. T. Haniš)
- Vienna University of Technology, Division of Control & Process Automation, (group of doc. A. Schirrer)

Joining their research backgrounds, the three involved research institutes will collaborate and exchange on developing and applying nonlinear optimal control methods (nonlinear model-predictive control formulations, estimation problems, parameter identification problems) to industrial application settings in the area of vehicle dynamics. Control tasks that have not been feasible before (e.g., highly-integrated nonlinear drive train optimization) seem feasible by extending and applying nonlinear explicit model-predictive control tools. When successful, these tools allow complex, nonlinear, constraint optimal control to be computed fast enough for realtime control on cheap hardware.

6.2.4 APVV SK-FR-2019-0004: Optimal design and control of processes (R. Paulen)

Period: 2020 – 2021

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (R. Paulen, M. Fikar, C. Valero, M. Mojto)
- Institut National Polytechnique de Lorraine (INPL) - Ecole Nationale Supérieure des Industries Chimiques (ENSIC) (M. A. Latifi, F. Lesage, Alexis Courtais, Fatima Mtamoros Marin)

The goal of this project is to enhance the cooperation of scientists who share common research interests in the development and application of advanced algorithms for design 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, process control and engineering. The scientific goals of the cooperation are to develop methodologies for shape optimization of production plants, effective parameter and state estimation of nonlinear dynamic systems, and techniques of optimal control. Software implementations will be delivered as a 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.

6.2.5 KA107 - Mobility of students and university employees between program countries and partner countries (STU - Thailand) (R. Paulen)

Period: 2020 – 2023

The goal of the project is to mutually reinforce teaching and research activities between the partners STU and Chulalongkorn University (Bangkok, Thailand) in the area of chemical engineering and process control. This goal will be reached by student, research, and academic mobilities that will result in development of research potential of partners and in an increase of students' and employees' qualification. Chulalongkorn University (CU) is the best thai technical university in the long term. Its history counts more than 100 years. During this time, CU made it to be among the top 50 universities in Asia. It is ranked at 247th place in QS University Rankings.

6.3 Research Projects in Slovak Republic

6.3.1 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.

6.3.2 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.

6.3.3 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.

6.3.4 VEGA 1/0545/20: Advanced Control of Energy Intensive Processes with Uncertainties in Chemical, Biochemical and Food Technologies (M. Bakošová)

Period: 2020 – 2023

The research project deals with the development of advanced control methods and algorithms for systems with uncertainties whose implementation will provide significant energy savings in control of energy intensive processes in chemical, biochemical and food technologies. The core of the project is the development of methods and design of algorithms for predictive control, robust predictive control and fuzzy control of systems with uncertainty. Computational efficiency and feasibility in practice will be taken into account when designing control algorithms. Designed control algorithms, controllers, and control structures will be tested by simulations and experiments in laboratory conditions and will be compared according to energy consumption with conventional control approaches. The controlled processes will be chemical reactors, biochemical reactors, heat exchangers, distillation columns and other energy intensive processes typical for chemical, biochemical and food technologies.

6.3.5 Safe process control focused on energy and cost savings (M. Horváthová)

Period: 2020 – 2021

Heat exchangers and chemical reactors are present in almost every industrial production.At present, the control of heat exchangers and chemical reactors does not meet energy standards of the 21st century.Therefore, of the areaswith a high potential for energy savings in industry, is the design of optimal and safe control of heat exchangers and chemical reactors. The main goal of this project is to derive, apply and analyze effective advanced methods to control these energy-intensive processes with regard to safety, energy savings and costs. These advanced control methods will be based on convex optimization. Another goal is to reduce computational complexity over conventional advanced control methods, to increase their applicability in industry. When applied, these new advanced methods will bring significant energy and cost savings. Energy efficiency is a key role in achieving greater objectives, including a healthy economy and sustainable industrial development. Minimizing energy waste is a fundamental pillar in achieving these objectives. Reducing the energy consumption of a technological process also results in a reduction of negative impacts on the environment.

6.3.6 Heart-Disease Diagnostic in Real Time with Neural Networks (M. Klaučo)

Period: 2019 – 2020

The presented project's main scientific goal is to create a new type of affordable biometric monitoring device for immediate detection of heart disease, called ECG-Holter. The device's task will be to continuously monitor biometric signals on the human body, which will be evaluated in real-time. The evaluation of these signals will be performed using the designed optimal neural network, which will take place directly on the ECG-Holter.

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)
- Institute of Automatic Control, Faculty of Automatic Control, Electronics and Computer Science, Silesian University of Technology, Gliwice, Poland (Modelling and control of heat exchangers)
- Department of Mechanical System Engineering, Faculty of Engineering, Shinshu University, Nagano, Japan (Modelling and control of the plants with quantized inputs)

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
- TESLA Blue Planet s. r. o., Liptovský Hrádok

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 (R. Paulen)
- IEEE (M. Fikar, M. Klaučo)
- 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, Ľ. 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)

P. Beke	Photovoltaic Panel with Automatic Tracking of Light Source (Kalúz, M.)
T. N. Hai	Modelling and Control of a Biotechnological Reactor for Ethanol Production (Bakošová, M.)
L. Homolová	Digital Twin of a Heat Exchanger (Kvasnica, M.)
D. Chowaniecová	Web Application for Data Input and Processing (Čirka, Ľ.)
M. Krištof	Modelling and Control of a Fermentaion Process for Ethanol Production (Bakošová, M.)
J. Puk	Mathematical Model and Control of Chemical Reactors with Variable Reaction Rate (Klaučo, M.)
M. Wadinger	Predictive Data Analytics based on Machine Learning (Kvasnica, M.)
A. Žabková	Robust Control of SISO Systems (Vasičkaninová, A.)

8.2 Master Theses (MSc. degree)

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

T. Ábelová	Static and Dynamic Optimization of Virtual Power Plants (Kvasnica, M.)
K. Fedorová	Decentralized Machine Learning and Optimization (Kvasnica, M.)
L. Galčíková	Explicit Model Predictive Control Design for Heat Exchanger (Oravec, J.)

M. Kintler	Guaranteed Identification and Its Use in Hybrid Modelling (Paulen, R.)
R. Kohút	Fast Nonlinear Model Predictive Control (Kvasnica, M.)
A. Morozov	Nonlinear Model Predictive Control of Rotary Pendulum (Klaučo, M.)
M. Nemeš	Wireless Sensor Network (Kalúz, M.)
M. Slávik	Model Predictive Control of Laboratory Neutralisation Plant (Oravec, J.)
R. Trautenberger	Software Development for Computing Properties of Chemical Compounds (Oravec, J.)

8.3 Dissertation Theses (PhD. degree)

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

A. Sharma	Mathematical Modeling and Optimal Operation of Membrane Processes (Fikar, M.)

9 Publications

9.1 Chapters or Pages in Books

1. A. Vasičkaninová – M. Bakošová – J. Oravec: *Fuzzy control of heat exchangers in series using complex control structures*, In *Advanced Analytic and Control Techniques for Thermal Systems with Heat Exchangers*, Editor(s): Libor Pekař, Academic Press Elsevier, pp. 287 – 306, 2020. doi: https://doi.org/10.1016/B978-0-12-819422-5.00003-7

9.2 Articles in Journals

1. M. Horváthová – J. Oravec – M. Bakošová: Efficient Convex-Lifting-Based Robust Control of a Chemical Reactor. *Chemical Engineering Transactions*, pp. 865 – 870, 2020. doi: https://doi.org/10.3303/CET2081145

2. Y. Jiang – J. Oravec – B. Houska – M. Kvasnica: Parallel MPC for Linear Systems with Input Constraints. *IEEE Transactions on Automatic Control*, pp. 1 – 8, 2020. doi: https://doi.org/10.1109/TAC.2020.3020827

3. K. Kusumo – L. Gomoescu – R. Paulen – S. García Muñoz – C. C. Pantelides – N. Shah – B. Chachuat: Bayesian Approach to Probabilistic Design Space Characterization: A Nested Sampling Strategy (in). *Industrial & Engineering Chemistry Research*, pp. 2396 – 2408, 2020. doi: https://doi.org/10.1021/acs.iecr.9b05006

4. J. Oravec – M. Horváthová – M. Bakošová: Energy efficient convex-lifting-based robust control of a heat exchanger. *Energy*, pp. 1 – 11, 2020. doi: https://doi.org/10.1016/j.energy.2020.117566

5. J. Oravec – M. Horváthová – M. Bakošová: Multivariable Robust MPC Design for Neutralization Plant: Experimental Analysis. *European Journal of Control*, 2020. doi: https://doi.org/10.1016/j.ejcon.2020.07.012

6. S. Thangavel – R. Paulen – S. Engell: Robust Multi-Stage Nonlinear Model Predictive Control Using Sigma Points. *Processes*, pp. 0851, 2020.

7. J. Theunissen – A. Sorniotti – P. Gruber – S. Fallah – M. Ricco – M. Kvasnica – M. Dhaens: Regionless Explicit Model Predictive Control

of Active Suspension Systems With Preview. *IEEE Transactions on Industrial Electronics*, pp. 4877 – 4888, 2020. doi: https://doi.org/10.1109/TIE.2019.2926056

8. A. Vasičkaninová – M. Bakošová – A. Mészáros: Control of heat exchangers in series using neural network predictive controllers. *Acta Chimica Slovaca*, pp. 41 – 48, 2020. doi: https://doi.org/10.2478/acs-2020-0007

9. A. Vasičkaninová – M. Bakošová – J. Oravec – M. Horváthová: Efficient Fuzzy Control of a Biochemical Reactor. *Chemical Engineering Transactions*, pp. 85 – 90, 2020. doi: https://doi.org/10.3303/CET2081015

9.3 Articles in Conference Proceedings

1. M. Furka – K. Kiš – M. Horváthová – M. Mojto – M. Bakošová: Identification and Control of a Cascade of Biochemical Reactors. In *2020 Cybernetics & Informatics (K&I)*, 2020.

2. A. R. Gottu Mukkula – P. Valiauga – M. Fikar – R. Paulen – S. Engell: Experimental Real Time Optimization of a Continuous Membrane Separation Plant (in). In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, pp. 11967 – 11974, 2020.

3. J. Holaza – J. Oravec – M. Kvasnica – R. Dyrska – M. Mönnigmann – M. Fikar: Accelerating Explicit Model Predictive Control by Constraint Sorting. In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, pp. 11520 – 11525, 2020.

4. M. Kalúz – Ľ. Čirka – M. Fikar: ELab: A Lightweight SCADA System for Control Engineering Research and Education. In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, pp. 17469 – 17474, 2020.

5. K. Kiš – M. Klaučo – A. Mészáros: Neural Network Controllers in Chemical Technologies. In *2020 IEEE 15th International Conference of System of Systems Engineering*, IEEE, pp. 397 – 402, 2020. doi: https://doi.org/10.1109/SoSE50414.2020.9130425

6. K. Kusumo – L. Gomoescu – R. Paulen – S. García Muñoz – C. C. Pantelides – N. Shah – B. Chachuat: Nested Sampling Strategy for Bayesian

Design Space Characterization (in). Editor(s): Sauro Pierucci, Flavio Manenti, Giulia Luisa Bozzano, Davide Manca, In *30th European Symposium on Computer Aided Process Engineering*, Elsevier, vol. 30, pp. 1957 – 1962, 2020. doi: https://doi.org/10.1016/B978-0-12-823377-1.50327-X

7. Y. Lohr – M. Klaučo – M. Fikar – M. Mönnigmann: Machine Learning Assisted Solutions of Mixed Integer MPC on Embedded Platforms (in). In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, 2020.

8. L. Lu – M. Kvasnica: Low-Complexity Stabilizing PWA Controllers for Linear Systems with Parametric Uncertainties. In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, pp. 7376 – 7381, 2020.

9. M. Mojto – K. Ľubušký – M. Fikar – R. Paulen: Advanced Process Control of an Industrial Depropanizer Column using Data-based Inferential Sensors (in). Editor(s): Sauro Pierucci, Flavio Manenti, Giulia Luisa Bozzano, Davide Manca, In *30th European Symposium on Computer Aided Process Engineering*, Elsevier, vol. 30, pp. 1213 – 1218, 2020. doi: https://doi.org/10.1016/B978-0-12-823377-1.50203-2

10. R. Paulen – L. Gomoescu – B. Chachuat: Nested Sampling Approach to Set-membership Estimation (in). In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, pp. 7318 – 7323, 2020.

11. A. Schirrer – T. Haniš – M. Klaučo – S. Thormann – M. Hromčík – S. Jakubek: Safety-extended Explicit MPC for Autonomous Truck Platooning on Varying Road Conditions (in). In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, 2020.

12. S. Thangavel – R. Paulen – S. Engell: Adaptive multi-stage NMPC using sigma point principles (in). In *European Control Conference 2020*, pp. 196 – 201, 2020.

13. S. Thangavel – R. Paulen – S. Engell: Multi-stage NMPC using sigma point principles. In *6th Conference on Advances in Control and Optimization of Dynamical Systems ACODS 2020*, Elsevier, vol. 53, pp. 386 – 391, 2020. doi: https://doi.org/10.1016/j.ifacol.2020.06.065

14. S. Thangavel – R. Paulen – S. Engell: Dual multi-stage NMPC using sigma point principles (in). In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, pp. 11394 – 11401, 2020.

15. C. E. Valero – M. Villanueva – B. Houska – R. Paulen: Set-Based State Estimation: A Polytopic Approach (in). In *Preprints of the 21st IFAC World Congress (Virtual), Berlin, Germany, July 12-17, 2020*, vol. 21, pp. 11428 – 11433, 2020.

16. A. Vasičkaninová – M. Bakošová – A. Mészáros: Advanced Control of Heat Exchangers in Series. In *2020 IEEE 15th International Conference of System of Systems Engineering*, IEEE, pp. 385 – 390, 2020. doi: https://doi.org/10.1109/SoSE50414.2020.9130477

9.4 Technical Reports

1. M. Kvasnica: Learning More from Less Data: When Quality Trumps Quantity (Workshop at IFAC World Congress 2020). 2020.

9.5 Certificates of Authorship, Patents, Inventions

1. J. Oravec – M. Bakošová: PIDDESIGN (in Slovak). 2020.

10 International Visits

10.1 Visits at our Department

Scientific Seminars

• 24.2.2019	M. Moennigmann	Big Data and System Identification: Challenges and Opportunities (RUB Bochum, Germany, University of Pisa, Italy)

Research Visits

• 17-28.8.2020	V. Cibulka D. Efremov	Tri-lateral project DS-FR-19-0031 Full-Authority Vehicle Control Strategy (Faculty of Electrical Engineering, CTU, Czech Republic)

10.2 Visits from our Department

Participation at Conferences

• 12–15.5.2020	R. Paulen	European Control Conference 2020, Saint Petersburg, Russia.
• 12–17.7.2020	Ľ. Čirka, M. Fikar, M. Kalúz, M. Klaučo, M. Kvasnica, J. Oravec, R. Paulen, C. E. Valero	IFAC World Congress 2020, Berlin, Germany.
• 27–29.10.2020	M. Kvasnica	Plenary lecture at the 21st International Carpathian Control Conference, Starý Smokovec, Slovak Republic.

Scientific Seminars

• 11.2.2020	M. Horváthová	Convex-lifting-based Robust Control (RUB Bochum, Germany)
• 11.2.2020	M. Furka	Development of Control Algorithms for Rotational Inverted Pendulum (RUB Bochum, Germany)

- 6.11.2020 M. Kvasnica Towards Fixed-Complexity Explicit Model Predictive Control (University of California in Berkeley, USA)

Research Visits

- 9-14.2.2020 P. Bakaráč Development of Indoor Environment Smart Sensors (RUB Bochum, Germany)
- 9-14.2.2020 M. Furka Development of Control Algorithms for Rotational Inverted Pendulum (RUB Bochum, Germany)
- 9-14.2.2020 M. Horváthová Constraints Removal in Nonlinear MPC (RUB Bochum, Germany)

11 Miscellaneous

11.1 Awards

- Doc. Ing. J. Oravec, PhD.
  - Awarded as Young researcher of Slovak University of Technology.
- Team of doc. Ing. M. Kvasnica, PhD.
  - Awarded as Excellent team of Slovak University of Technology.
- Doc. Ing. M. Kvasnica, PhD. and Ing. M. Klaučo, PhD.
  - Awarded by Slovak literary fund for their publication „MPC – Based Reference Governors“ in the category Scientific literature of the year 2019.
- Doc. Ing. R. Paulen, PhD.
  - Journal of Process Control Paper Prize for paper Set-membership Nonlinear Regression Approach to Parameter Estimation (N. D. Perić, R. Paulen, M. E. Villanueva, B. Chachuat).
- Ing. L. Galčíková
  - Student of the year 2020 at the Slovak University of Technology for an outstanding activity performed for the benefit of the STU.
- Ing. M. Horváthová
  - Student of the year 2020 at the Slovak University of Technology for outstanding study results.