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

2017

Address:

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

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Absent: J. Mikleš.

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1 Preface

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

Nowadays, information technologies and microprocessor-based and advanced process control represent important and acknowledged scientific branches. These branches more and more influence the economic and social growth in the whole world and successively also in Slovakia. The chemical, food 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. In the connection with these facts, all our graduates find their jobs without problems during the whole history of the department. It also confirms, that the education of the specialists in the information engineering and process control has been very attractive and its significance is even growing. The graduates of the department do well not only in the companies and institutions oriented on design and supplying of control systems for various technologies but also in the bank sector and they found their own firms respectively.

The main branch of teaching and research activities of the department si oriented to process control, optimal control, identification and modeling of systems, industrial automation, and on development of software packages for intelligent control systems. Second branch is devoted to information technologies, data management, and programming.

prof. Ing. Miroslav Fikar, DrSc.

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 2017.

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 post-graduate students have been educated since 1964. So far, more than four hundreds 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. has headed the department since 2003.

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 2000 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 of them continue in the four-year doctoral programs leading to the PhD degree.

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4 Teaching and Research Laboratories

Laboratory of Process Control:

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

Laboratory of Control Systems:

- Siemens-SIMATIC S-7 200, S-7 1200
- Lego Mindstorms NXT 2.0
- Thermo-optical System uDAQ28/LT
- Ball & Plate CE 151
- Magnetic Levitation

Laboratory of Industrial Technology:

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

Computer Laboratories:

- Linux based PCs
- Raspberry Pi
- Arduino
- Moving robots (cars)

Remote Laboratories: Control of technological processes via internet access

- Two-tank system
- Thermal-optical systems
- DC motor

5 Educational Activities

5.1 Bachelor Study

1st semester (Winter)		
Fundamentals of Matlab	0/0/2	Čirka, Oravec, Vasičkaninová
2nd semester (Summer)		
Fundamentals of Electrotechnics	0/2/0	Valo
Information Engineering and Information Systems	1/0/2	Čirka
Internet and Information Systems	0/0/2	Čirka
Spreadsheet and Database Systems for Data Processing	0/0/2	Čirka
3rd semester (Winter)		
Fundamentals of Language C	0/0/2	Bakaráč, Kvasnica
Fundamentals of Matlab	0/0/2	Čirka, Oravec, Vasičkaninová
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
Internet and Information Systems	0/0/2	Čirka
Laboratory of Process Control	0/0/2	Jelemenský, Vasičkaninová
Process Control	2/0/0	Bakošová
Programming I	2/0/2	Holaza, Kvasnica
Spreadsheet and Database Systems for Data Processing	0/0/2	Čirka

Web Technologies in Automation	0/0/2	Čirka
5th semester (Winter)		
Design of Information and Control Systems	2/0/3	Kalúz, Valo
Introduction to XML Technologies	1/0/1	Holaza, Kvasnica
Optimization	2/0/2	Bakaráč, Klaučo, Kvasnica
6th semester (Summer)		
Integrated Control in Process Industries	2/0/3	Bakošová, Vasičkaninová
Laboratory of Process Control	0/0/2	Jelemenský, Kalúz, Klaučo, Oravec, Valo, Vasičkaninová
Process Control	2/0/0	Bakošová
Programming II	1/0/2	Holaza, Kvasnica
Web Technologies in Automation	0/0/2	Čirka

5.2 Master Study

1st semester (Winter)		
Automatic Control Theory I	2/0/3	Fikar, Paulen
Control of Technological Processes	1/0/1	Bakošová, Vasičkaninová
Industrial Control Systems	0/0/2	Valo
Information Technology I	0/0/2	Čirka
Modelling in Process Industry	2/2/0	Bakošová, Vasičkaninová
Process Dynamics and Control	2/0/1	Bakošová, Vasičkaninová
Programming of Web Applications	1/0/2	Čirka
Technical Means of Automation	2/0/2	Kalúz

2nd semester (Summer)

Automatic Control Theory II	2/0/3	Fikar, Janeček
Identification	2/0/2	Čirka, Fikar
Information Engineering and Industrial Information Systems I	1/0/3	Kvasnica, Valo

3rd semester (Winter)

Automatic Control Theory III	2/0/2	Fikar, Oravec
Industrial Control Systems	0/0/2	Valo
Information Engineering and Industrial Information Systems II	2/0/2	Holaza, Kvasnica
Information Technologies II	0/0/2	Čirka
Network Fundamentals	0/0/2	Fikar
Optimisation of Processes and Plants	2/0/2	Klaučo, Kvasnica
Process Control Project	0/0/3	Kalúz
Project Software Systems	0/2/0	Klaučo, Kvasnica

4th semester (Summer)

Robust Control	1/2/0	Bakošová, Oravec

5.3 PhD Study

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	Fikar

5.4 Course Contents

5.4.1 Lectures in Bachelor Study

Information Engineering and Information Systems (1h/week, 2nd Static and dynamic pages, web technologies – HTML and XHTML, creation of html documents. HTML: structure of HTML document (head, body). HTML: text, links, ordered and unordered lists. HTML: graphics, tables. HTML: forms (methods, form elements, attributes), evaluation of form data. HTML: frames, applets, servlets CSS: introduction to formatting using cascade styles. CSS: colour, font, alignment, links. CSS: ordered and unordered 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.

Modeling (2h/week, 3rd semester) Introduction to process modeling, approaches to modeling, 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.

Process Control (2h/week, 4th and 6th 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) Basics of programming language C and C++. Programming language description, loops, conditions, methods, fields, basic algorithms and their usage during programs development. Preparation for advanced algorithms in Programming II course.

Optimization (2h/week, 5th semester) Introduction to optimization and motivating examples. Classification of optimization problems. Convex functions. Extrema of 1-D smooth functions. Extrema of n-D smooth functions. Analytical methods for unconstrained optimization. Constrained optimization with equality constraints. The Lagrange method for equality constrained optimization. Economic interpretation of Lagrange multipliers. Inequality constrained optimization. Karush-Kuhn-Tucker conditions. Simplex method for linear programming. Quadratic programming. Applications of linear and quadratic programming. Introduction to nonlinear optimization. Introduction to mixed-integer optimization.

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) The course is divided into two 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.

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 and 3rd 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 creating I. Custom application creating II. Simulink I. Simulink II. Simulink III. Simulink IV.

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.

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.

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.

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.

Laboratory Exercises of Process Control (2h/week, 4th and 6th semester) MATLAB/Simulink as a simulation tool for LEPC. Laplace transform as a mathematical tool for LEPC. Input-output description of dynamic systems, transfer functions, poles and zeros. Step responses and impulse responses of dynamic systems. Mathematical models and dynamic behavior of processes of chemical technology. Feedback control. PID controllers and their properties in feedback control. Controller synthesis and control of processes of chemical technology. Stability. Reference tracking and disturbance rejection. Analytical methods for controller synthesis. Experimental methods for controller synthesis. Control of tanks. Control of heat exchangers.

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.

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.

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.

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.

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.

Bachelor Project (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.

5.4.3 Lectures in Master Study

Programming of Web Application (1h/week, 1st semester) PHP language a SQL database systems basics. Internet programming. Process or other database sources data and measurement processing.

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.

Technical Means of Automation (2h/week, 1st semester) Automated process control systems. Acquisition and basic processing of process variables. The architecture of measurement systems. Industrial process controllers and stations. Programmable logic controllers. Standard IEC 61131. Distributed control systems. Sensors, actuators, motors, inverters, management.

Modeling in Process Industry (2h/week, 1st semester) Introduction to modeling in process engineering, modeling of processes with discretely and continuously distributed parameters: tubular heat exchangers, tray distillation columns, packed distillation columns, packed absorption columns; modeling of extractors without and with chemical reactions; modeling of tubular chemical reactors without and with catalyst; modeling of batch and semi-batch processes: chemical reactors, extractors and distillation columns.

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

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.

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.

Identification (2h/week, 2nd semester) The identification of dynamic systems from their step responses of the 1st and 2nd order, Strejc, Šalamon, Hudzovič, Söderström methods. Statistical identification methods. Classification of models for experimental identification. Least-square method, recursive least- square method, lemma about the matrix inversion, REFIL, LDFIL, LDDIF algorithms. Prediction error method and auxiliary variable method. Using of recursive identification methods for identification of multi-variable and continuous-time systems. Aspects of the least square method and identification of static models, passive and active experiment.

Automatic Control Theory II (2h/week, 2nd semester) Z-transform. Discrete-time process models. State-space discrete-time models. Transfer funcions of discrete-time systems. Stability of discrete-time systems. Design of digital process controllers. DB control. Calculus of variations. Ponryagins principle of minimum. Dynamic programming. Optimal state feedback, LQ control. Kalman filter

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.

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.

Predictive Control (1h/week, 4th semester) Introduction to principles of the predictive control, types of models and objective functions. Formulation of a problem as the optimization problem with aim to predictive control

of the chemical technology systems. Introduction to predictive control and definition of the main terms. Explanation of the norms and their application in LP and QP problems. Construction of the optimization problems and their implementation in YALMIP. State-tracking, output tracking, predictive control with integrator and time-varying reference tracking. Explicit model predictive control.

Robust Control (1h/week, 4th semester) Introduction to robust control of uncertain systems. First part covers the robust analysis subject to various types of structured and non-structured uncertain parameters. The second part provides an insight into the problem of robust synthesis using various methods, e.g., D-partition, Small Gain Theorem, Linear-Matrix-Inequality-based method, etc. Essential aspects of robust controller design for the uncertain systems of chemical and food industry.

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

5.4.4 Laboratory Exercises in Master Study

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.

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.

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.

Information Technology II (2h/week, 3rd semester) Students have knowledge of making static and dynamic websites. They are able to create simple web pages. They know fundamentals of HTML, CSS, PHP and SQL.

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.

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.

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.

Project Software Systems (2h/week, 3rd semester) The course is divided into four main parts. The first one introduces students to basic concepts of version control systems (VCS) and explains differences between the centralized approach and the distributed one. The second part explains the usage of the Mercurial distributed VCS and shows how to operate it from the command line. The third part discusses the GIT distributed VCS. The final part is devoted to graphical user interfaces for VCS adn web-based collaboration platforms.

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.

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.

6 Current Research Activities

Research at the Department of Process Control orients to advanced control theory and modeling 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, J. Mikleš) Modeling 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 modeling 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.

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. Fikar, M. Kvasnica, M. Klaučo, J. Holaza, P. Bakaráč) 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) 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) 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) 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) 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 Research Projects in Slovak Republic

6.2.1 VEGA 1/0403/15: Verifiably Safe Optimal Control (M. Kvasnica)

Period: 2015 – 2018

This research project is devoted to design, synthesis, and implementation of optimal control systems for process control applications which require rigorous guarantees that the control system will exhibit desired safety and economical properties. The parameters of safety and economical behavior are divided into theoretical properties (closed-loop stability, recursive feasibility and satisfaction of process constraints), and practical properties (guaranteed execution of the optimization algorithm on platforms with restricted computational resources, correct behavior of the control system under quantization and under failures of the communication channels). Nowadays, these properties are verified by extensive testing, which is time consuming and expensive. Therefore the main goal of the project is to develop a unified methodology which allows to design optimal control systems in which safety properties can be imposed and verified already at the design stage.

6.2.2 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.

6.2.3 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.

6.2.4 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.

6.2.5 Advanced Optimal and Safety Oriented Control of Energy-Intensive Processes (M. Klaučo)

Internal Grant of the Slovak University of Technology in Bratislava

Period: 2017

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.

6.2.6 Machine Learning and Artificial Intelligence in Process Control and Automatio (M. Kvasnica)

Postdoc research stays at the Slovak University of Technology in Bratislava
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 International Scientific Projects

6.3.1 Training in Embedded Predictive Control and Optimization (M. Fikar, M. Kvasnica)

Period: 2014–2018

Financing: European Commission – Framework Program 7, MC ITN

TEMPO is an international PhD program for highly motivated young scientists, where state-of-the-art research is combined with a comprehensive training program. The network is funded by the European Community's Seventh Framework program. TEMPO addresses the needs of European companies and society for embedded control technology, through training on cutting edge research in the rapidly emerging inter-disciplinary field of embedded predictive control and optimization.

Ten partners from academia and industry, as well as three associated partners will provide a multi-national and interdisciplinary training infrastructure, designed to equip the participating fellows with the necessary knowledge and set of tools to pursue successful careers.

Project main page: http://www.itk.ntnu.no/tempo/

6.3.2 APVV SK-CN-2015-0016: Robust Model Predictive Control Meets Robotics

Period: 2016 – 2017

Partners:

- Slovak University of Technology in Bratislava (M. Kvasnica, J. Oravec, M. Bakošová, M. Klaučo, J. Drgoňa)
- ShanghaiTech University (B. Houska, X. Feng, Y. Jiang, Y. Zha)

China and Slovakia have an enormous potential for innovative research in robotics and control. The goal of this project is to bring together a group of young researchers whose aim is to create robust model predictive controllers with emphasis on the implementation of advanced control procedures and applications in robotics. We will build upon advanced linear matrix inequality techniques and real-time control software to develop novel types of autonomous and intelligent control algorithms for uncertain processes that are far beyond the state-of-the-art. The research shall be carried out by scientist and PhD students in Slovakia and China, who will visit each other on a regular basis, thereby creating channels for technological as well as intercultural exchange. At the same time, we will showcase innovative research on modern technologies that shall educate the next generation of control and robotic scientists in China and Slovakia, thereby creating a huge potential for academic breakthroughs as well as successful spin-offs in both countries.

6.3.3 APVV SK-FR-2015-0001: Real Time Optimal Process Control

Period: 2016 – 2017

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (M. Fikar, M. Jelemenský, D. Pakšiová, R. Paulen, A. Sharma)
- Institut National Polytechnique de Lorraine (INPL) – Ecole Nationale Supérieure des Industries Chimiques (ENSIC) (M. A. Latifi, F. Lesage, R. Hriez, R. Bousbia-Salah)

Finding the optimal solution to a problem is an every day struggle. The mankind has been in search of optimality to any problem in every aspect of life such as work. These optimization problems can differ in many aspects. For

example in research work we want to find the optimal control for distillation columns, heat exchangers or membrane processes to maximize the profit and the minimize the production costs. In normal life we can also face many optimization problems without realizing it. These can be for example which way should I choose to come to work in minimum time. To solve all these optimization problems we can use several optimization methods from the field of dynamic optimization. In this research project we will focus mainly on the chemical processes.

6.3.4 Embedded Optimal Control

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.

7 Cooperations

7.1 Cooperations in Slovakia

- Institute of Robotics and Cybernetics, 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 Automotive Mechatronics, Faculty of Electrical Engineering and Informatics, 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
- Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Košice, Košice
- ProCS s.r.o, Actemium Slovakia, Šaľa
- Slovnaft, Inc., Bratislava
- Schneider Electric (Slovakia) s.r.o., Bratislava
- Regotrans-Rittmeyer Slovakia s.r.o., Bratislava

7.2 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)
- Department of Mechanical Engineering, Division of Applied Mechanics and Energy Conversion (TME), KU Leuven – University of Leuven, Leuven, Belgium (Simulation of Thermal Systems)
- 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)
- CentraleSupélec, Paris, France (MPC)

- Automatic Control Laboratory, ETH Zurich, Switzerland (Model Predictive Control, Modeling, analysis, and control of hybrid systems)
- University of Dortmund, Dortmund, Germany (Model Predictive Control)
- Technical University of Budapest, Budapest, Hungary (Modelling of chemical processes)
- Corvinus University of Budapest, Budapest, Hungary (Membrane Engineering)
- University of Veszprem, Hungary (Environmental engineering, Bioengineering projects)
- Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College London, United Kingdom (Global optimization, Parameter estimation)
- NTNU Trondheim, Norway (Process Control, MPC)
- DeustoTech, Faculty of Engineering, University of Deusto, Bilbao, Spain (Control education, Remote laboratories)

7.3 Membership in Domestic Organizations and Societies

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

7.4 Membership in International Organizations and Societies

- International Federation of Automatic Control, Laxenburg, Austria (M. Fikar)
- European Federation of Biotechnology, Brussels, Belgium (A. Mészáros)
- New York Academy of Sciences, New York, USA (A. Mészáros)
- European Union Control Association (M. Kvasnica)
- IEEE (M. Fikar)

8 Theses and Dissertations

8.1 Bachelor Theses (BSc. degree)

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

Boroš, D.	Application of Raspberry Pi on fluid tank control (Valo, R.)
Dudáková, Z.	Programming NXT Robots (Holaza, J.)
Furka, M.	Parameter Design of PID Controllers by SIMC (Skogestad IMC) (Vasičkaninová, A.)
Horváthová, M.	Advanced control of chemical reactor (Oravec, J.)
Kiš, K.	Creation of a remote SCADA/HMI for a laboratory batch membrane process station experiment. (Valo, R.)
Koncz, I.	Creating Video Instructions and Video Presentations of Our Laboratory Experiments (Valo, R.)
Nosko, J.	The Creation of SSC Portal (Čirka, Ľ.)
Tkáč, T.	Model Predictive Control of Intelligent Buildings (Kvasnica, M.)

8.2 Master Theses (MSc. degree)

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

Bakaráč, P.	Development and Control of Inverted Pendulum (Kalúz, M.)
Batárová, K.	Advanced control methods of pH in a chemical reactor (Holaza, J.)
Jakabšic, J.	Development of Graphical User Interface for Intelligent Room (Kalúz, M.)

Koniar, S.	Support control systems based on MPC (Kvasnica, M.)
Mikušová, N.	Development of Software Tools for Automation and Control in JULIA Environment (Fikar, M.)
Mišenko, M.	Stabilisation of Column Feed using APC (Fikar, M.)

8.3 PhD's Theses (PhD. degree)

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

Blažek, S.	Optimal Path Planning for Heterogenous Multi-Vehicle Systems (Fikar, M.)
Drgoňa, J.	Model Predictive Control with Applications in Building Thermal Comfort Control (Kvasnica, M.)
Ingole, D.	Embedded Implementation of Explicit Model Predictive Control (Kvasnica, M.)
Klaučo, M.	MPC-based Reference Governors: Theory and Applications (Kvasnica, M.)

9 Publications

9.1 Articles in Journals

1. Bakošová, M. – Oravec, J. – Vasičkaninová, A. – Mészáros, A.: Neural-Network-Based and Robust Model-Based Predictive Control of a Tubular Heat Exchanger. *Chemical Engineering Transactions*, pp. 301 – 306, 2017. doi: https://doi.org/10.3303/CET1761048

2. Drgoňa, J. – Klaučo, M. – Janeček, F. – Kvasnica, M.: Optimal control of a laboratory binary distillation column via regionless explicit MPC. *Computers & Chemical Engineering*, pp. 139 – 148, 2017. doi: https://doi.org/10.1016/j.compchemeng.2016.10.003

3. Klaučo, M. – Kalúz, M. – Kvasnica, M.: Real-time implementation of an explicit MPC-based reference governor for control of a magnetic levitation system. *Control Engineering Practice*, pp. 99 – 105, 2017. doi: https://doi.org/10.1016/j.conengprac.2017.01.001

4. Klaučo, M. – Kvasnica, M.: Control of a boiler-turbine unit using MPC-based reference governors. *Applied Thermal Engineering*, pp. 1437 – 1447, 2017. doi: https://doi.org/10.1016/j.applthermaleng.2016.09.041

5. Klaučo, M. – Valo, R. – Drgoňa, J.: Reflux control of a laboratory distillation column via MPC-based reference governor. *Acta Chimica Slovaca*, pp. 139 – 143, 2017. doi: https://doi.org/10.1515/acs-2017-0023

6. Nguyen, N. A. – Olaru, S. – Rodríguez-Ayerbe, P. – Kvasnica, M.: Convex liftings-based robust control design. *Automatica*, pp. 206 – 213, 2017. doi: https://doi.org/10.1016/j.automatica.2016.11.031

7. Oravec, J. – Klaučo, M. – Kvasnica, M. – Löfberg, J.: Computationally Tractable Formulations for Optimal Path Planning with Interception of Targets' Neighborhoods. *Journal of Guidance, Control, and Dynamics*, pp. 1221 – 1230, 2017. https://doi.org/10.2514/1.G002096

8. Oravec, J. – Trafczynski, M. – Bakošová, M. – Markowski, M. – Mészáros, A. – Urbaniec, K.: Robust Model Predictive Control of Heat Exchanger Network in the Presence of Fouling. *Chemical Engineering Transactions*, pp. 334 – 342, 2017. doi: https://doi.org/10.3303/CET1761054

9. Picard, D. – Drgoňa, J. – Kvasnica, M. – Helsen, L.: Impact of the controller model complexity on model predictive control performance for buildings. *Energy and Buildings*, pp. 739 – 751, 2017. doi: https://doi.org/10.1016/j.enbuild.2017.07.027

10. Sharma, A. – Jelemenský, M. – Paulen, R. – Fikar, M.: Modeling and optimal operation of batch closed-loop diafiltration processes. *Chemical Engineering Research and Design*, pp. 198 – 210, 2017. doi: https://doi.org/10.1016/j.cherd.2017.04.016

11. Vasičkaninová, A. – Bakošová, M. – Čirka, Ľ. – Kalúz, M. – Oravec, J.: Robust Controller Design for a Laboratory Heat Exchanger. *Applied Thermal Engineering*, pp. 1297 – 1309, 2017. doi: https://doi.org/10.1016/j.applthermaleng.2017.09.086

12. Vasičkaninová, A. – Bakošová, M. – Oravec, J. – Mészáros, A.: Neural Network Predictive Controller Design for Counter-Current Tubular Heat Exchangers in Series. *Chemical Engineering Transactions*, pp. 121-126, 2017. doi: https://doi.org/10.3303/CET1761018

9.2 Articles in Conference Proceedings

1. Bakaráč, P. – Kalúz, M. – Čirka, Ľ.: Design and Development of a Low-cost Inverted Pendulum for Control Education. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 398 – 403, 2017.

2. Bousbia-Salah, R. – Lesage, F. – Fikar, M. – Latifi, M. A.: Closed-loop Dynamic Optimization of a Polymer Grafting Batch Reactor. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 376 – 379, 2017.

3. Čirka, Ľ. – Kalúz, M.: A Web-based Tool for Design of Simulink Models. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 92 – 97, 2017.

4. Dani, S. – Sonawane, D. – Ingole, D. – Patil, S.: Performance Evaluation of PID, LQR and MPC for DC Motor Speed Control. Editor(s): Chanakya Jha, In *2nd International Conference for Convergence in Technology, Pune, India*, IEEE, Pune, pp. 1 – 7, 2017.

5. Drgoňa, J. – Takáč, Z. – Horňák, M. – Valo, R. – Kvasnica, M.: Fuzzy Control of a Laboratory Binary Distillation Column. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 120 – 125, 2017.

6. Fikar, M.: Optimal Control of Batch Membrane Processes (in Slovak). Editor(s): Zdeněk Palatý, In *Membránové procesy pro udržitelný rozvoj*, Česká membránová platforma, z.s, 2017.

7. Gottu Mukkula, A. R. – Paulen, R.: Robust model-based design of experiments for guaranteed parameter estimation. Editor(s): Antonio Espuña, Moisès Graells and Luis Puigjaner, In *27th European Symposium on Computer-Aided Process Engineering*, Elsevier, pp. 1639 – 1644, 2017.

8. Holaza, J. – Klaučo, M. – Kvasnica, M.: Solution Techniques for Multi-Layer MPC-Based Control Strategies. In *Preprints of the 20th IFAC World Congress, Toulouse, France*, vol. 20, 2017.

9. Holaza, J. – Valo, R. – Klaučo, M.: A Novel Approach of Control Design of the pH in the Neutralization Reactor. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 191 – 196, 2017.

10. Ingole, D. – Drgoňa, J. – Kalúz, M. – Klaučo, M. – Bakošová, M. – Kvasnica, M.: Model Predictive Control of a Combined Electrolyzer-Fuel Cell Educational Pilot Plant. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 147 – 154, 2017.

11. Ingole, D. – Drgoňa, J. – Kvasnica, M.: Offset-Free Hybrid Model Predictive Control of Bispectral Index in Anesthesia. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 422 – 427, 2017.

12. Ingole, D. – Kvasnica, M. – De Silva, H. – Gustafson, J.: Reducing Memory Footprints in Explicit Model Predictive Control using Universal Numbers. In *Preprints of the 20th IFAC World Congress, Toulouse, France*, vol. 20, pp. 12100 – 12105, 2017.

13. Janeček, F. – Klaučo, M. – Kalúz, M. – Kvasnica, M.: OPTIPLAN: A Matlab Toolbox for Model Predictive Control with Obstacle Avoidance. In *Preprints of the 20th IFAC World Congress, Toulouse, France*, vol. 20, 2017.

14. Janeček, F. – Klaučo, M. – Kvasnica, M.: Trajectory Planning and Following for UAVs with Nonlinear Dynamics. Editor(s): M. Fikar and M. Kvasnica, In *Proceedings of the 21st International Conference on Process Control*, Slovak Chemical Library, Štrbské Pleso, Slovakia, pp. 333 – 338, 2017.

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10 Miscellaneous

10.1 Awards

- Assoc. prof. Ing. Michal Kvasnica, PhD. was awarded *Prize of the Literary Fund of the Slovak Republic* for the most frequently cited article and *Prize of the Literary Fund of the Slovak Republic* for the second highest number citations in 3 years.
- Ing. Radoslav Paulen, PhD. received the *Best Researcher of Slovak University of Technology 2017* award given by the rector of the Slovak University of Technology in Bratislava
- Ing. MSc. Martin Klaučo, PhD. received the *Award of the Rector* of the Slovak University of Technology for achievements in PhD studies.
- Ing. MSc. Martin Klaučo, PhD. received the *Award of the Dean* of the Faculty of Food and Chemical Technology for research achievements during PhD studies.

10.2 Events

Following events were co-organized by the Department of Information Engineering and Process Control:

- *21st International Conference on Process Control 2017* was held in Štrbské Pleso, Slovakia on June 6$^{\text{th}}$ to June 9$^{\text{th}}$. The objective of this three-day conference was to bring together theory-experts and control systems specialists, to evaluate the new possibilities of techniques, design procedures and instruments in process control projects.
- *TEMPO Summer School 2017* was a three-day intensive training was the Hardware Implementation of Embedded Optimisation with the aim to give hands-on experience in implementation of predictive model controllers (MPC) on embedded hardware like field-programmable gateway arrays (FPGAs), programmable logic controllers (PLCs), and Arduino microcontrollers. The summer school was held at Faculty of Food and Chemical Technology on July 17$^{\text{th}}$-21$^{\text{st}}$, 2017.