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

STU FCHPT

ANNUAL REPORT

IAM

2023

Address:

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

Faculty of Chemical and Food Technology
Slovak University of Technology in Bratislava

Radlinského 9
812 37 Bratislava
Slovak Republic

Telephone:	+ 421 – 2 – 59 325 366
E-mail:	office@uiam.sk
Fax:	+ 421 – 2 – 59 325 340
Web:	https://www.uiam.sk

From left: R. Paulen, D. Šišoláková, T. Ábelová, R. Fáber, M. Klaučo, M. Wadinger, D. Dzurková, R. Kohút, K. Fedorová, J. Oravec, L. Galčíková, P. Bakaráč, J. Holaza, M. Horváthová, Ľ. Čirka, E. Pavlovičová, J. Vargan, M. Fikar, P. Valábek, M. Kalúz

Absent: M. Furka, K. Kiš, M. Kvasnica, K. Macušková, M. Mojto, C. E. Valero, R. Valo

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 sixty-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 (four-year bachelor study in a remedial study form) in the study program Process Control, 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 exception. Technology can only be successful in the competition with optimization and advanced control systems or with using information technologies.

The department's main branch of teaching and research activities is oriented towards process control, optimization-based control design, identification and modelling of dynamical systems, industrial automation, and developing 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 its graduates to be competitive in this dynamic 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 excellent in companies and institutions oriented towards the design and installation of control systems for various technologies and in the fintech sector or as entrepreneurs, founding their own companies.

As of September 2020, the department is lead by M. Klaučo together with the deputy R. Paulen.

doc. 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 2023.

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 five hundred specialists and more than fifty PhD students have been graduated here and five 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. Current head of the department is doc. Ing. MSc. Martin Klaučo, PhD.

Department of Information Engineering and Process Control is one of the 24 departments at the FCFT STU, where students obtain specialization in various branches of chemical technology or chemical engineering. Approximately 1,000 students are currently enrolled in the 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 graduates continue in the four-year doctoral programs leading to the PhD. degree.

3 Staff

3.1 Head of Department

Head of Department

doc. Ing. MSc. Martin Klaučo, PhD. — Telephone: + 421 – 2 – 59 325 345, E-mail: martin.klauco@stuba.sk

Deputy of Department

doc. Ing. Radoslav Paulen, PhD. — Telephone: + 421 – 2 – 59 325 730, E-mail: radoslav.paulen@stuba.sk

Office

Katarína Macušková — Telephone: + 421 – 2 – 59 325 366, E-mail: katarina.macuskova@stuba.sk

3.2 Full Professors

prof. Ing. Miroslav Fikar, DrSc. — Telephone: + 421 – 2 – 59 325 367, E-mail: miroslav.fikar@stuba.sk

prof. Ing. Michal Kvasnica, PhD. — Telephone: + 421 – 2 – 59 325 352, E-mail: michal.kvasnica@stuba.sk

prof. Ing. Alajos Mészáros, PhD., Dr.h.c., professor emeritus — Telephone: + 421 – 2 – 59 325 149, E-mail: alajos.meszaros@stuba.sk

prof. Ing. Ján Mikleš, DrSc., professor emeritus — Telephone: + 421 – 2 – 59 325 343, E-mail: jan.mikles@stuba.sk

3.3 Associate Professors

Ing. Ľuboš Čirka, PhD. — Telephone: + 421 – 2 – 59 325 355, E-mail: lubos.cirka@stuba.sk

doc. Ing. MSc. Martin Klaučo, PhD. — Telephone: + 421 – 2 – 59 325 345, E-mail: martin.klauco@stuba.sk

doc. Ing. Juraj Oravec, PhD. — Telephone: + 421 – 2 – 59 325 364, E-mail: juraj.oravec@stuba.sk

doc. Ing. Radoslav Paulen, PhD. — Telephone: + 421 – 2 – 59 325 730, E-mail: radoslav.paulen@stuba.sk

3.4 Assistant Professors

Ing. Peter Bakaráč, PhD. — Telephone: + 421 – 2 – 59 325 351, E-mail: peter.bakarac@stuba.sk

Ing. Juraj Holaza, PhD. — Telephone: + 421 – 2 – 59 325 354, E-mail: juraj.holaza@stuba.sk

Ing. Michaela Horváthová, PhD. — Telephone: + 421 – 2 – 59 325 350, E-mail: michaela.horvathova@stuba.sk

Ing. Richard Valo, PhD. Telephone: + 421 – 2 – 59 325 354
E-mail: richard.valo@stuba.sk

3.5 Researchers

Ing. Martin Kalúz, PhD. Telephone: + 421 – 2 – 59 325 355
E-mail: martin.kaluz@stuba.sk

3.6 PhD Students

Ing. Tereza Ábelová Telephone: + 421 – 2 – 59 325 356
E-mail: tereza.abelova@stuba.sk

Ing. Diana Dzurková Telephone: + 421 – 2 – 59 325 356
E-mail: diana.dzurkova@stuba.sk

Ing. Rastislav Fáber Telephone: + 421 – 2 – 59 325 349
E-mail: rastislav.faber@stuba.sk

Ing. Kristína Fedorová Telephone: + 421 – 2 – 59 325 176
E-mail: kristina.fedorova@stuba.sk

Ing. Matúš Furka Telephone: + 421 – 2 – 59 325 354
E-mail: matus.furka@stuba.sk

Ing. Lenka Galčíková Telephone: + 421 – 2 – 59 325 350
E-mail: lenka.galcikova@stuba.sk

Ing. Karol Kiš Telephone: + 421 – 2 – 59 325 176
E-mail: karol.kis@stuba.sk

Ing. Roman Kohút Telephone: + 421 – 2 – 59 325 176
E-mail: roman.kohut@stuba.sk

Ing. Martin Mojto Telephone: + 421 – 2 – 59 325 349
E-mail: martin.mojto@stuba.sk

Ing. Erika Pavlovičová Telephone: + 421 – 2 – 59 325 356
E-mail: erika.pavlovicova@stuba.sk

Ing. Rudolf Trautenberger E-mail: rudolf.trautenberger@stuba.sk

Ing. Patrik Valábek Telephone: + 421 – 2 – 59 325 351
E-mail: patrik.valabek@stuba.sk

Ing. Jozef Vargan Telephone: + 421 – 2 – 59 325 349
E-mail: jozef.vargan@stuba.sk

MSc. Carlos E. Valero Telephone: + 421 – 2 – 59 325 349
E-mail: carlos.valero@stuba.sk

Ing. Marek Wadinger Telephone: + 421 – 2 – 59 325 362
E-mail: marek.wadinger@stuba.sk

3.7 Technical Staff

Katarína Macušková	Telephone: + 421 – 2 – 59 325 366 E-mail: katarina.macuskova@stuba.sk
Danica Šišoláková	Telephone: + 421 – 2 – 59 325 363 E-mail: danica.sisolakova@stuba.sk

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)
- Smart Eco Greenhouse VESNA

Laboratory of Control Systems:

- Lego Mindstorms NXT 2.0
- Thermo-optical System uDAQ28/LT
- Flexy 2.0
- Laboratory Food Machine
- Linear Inverted Pendulum
- Rotary Inverted Pendulum (Furuta)

Laboratory of Industrial Technology:

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

Computer Laboratories:

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

5 Educational Activities

5.1 Bachelor Study

1st semester (Winter)		
Electrical engineering	0/0/2	Kalúz
Fundamentals of Matlab	0/0/2	Bakaráč, Fáber, Kohút, Pavlovičová, Vargan, Wadinger
Tools of Technical Computing I	0/2/0	Valábek
2nd semester (Summer)		
Dynamic Systems	2/2/0	Paulen, Fáber
Embedded Systems I	0/0/2	Dzurková
Informatics I	0/0/2	Holaza
Internet and Information Systems	0/0/2	Čirka
Spreadsheet and Database Systems for Data Processing	0/0/2	Čirka, Mojto
Tools of Technical Computing II	0/2/0	Kohút
3rd semester (Winter)		
Computer-based Simulation	1/0/1	Paulen
Informatics II	0/0/2	Bakaráč
Operating Systems I	0/2/0	Valábek
Presentation skills I	0/2/0	Horváthová
Web Technologies I	1/0/3	Čirka
4th semester (Summer)		
Introduction to Process Control	1/0/1	Klaučo, Bakaráč, Furka
Laboratory Exercises of Process Control	0/0/2	Fedorová, Galčíková, Horváthová
Logic Control	2/2/0	Kalúz, Valo
Operating Systems II	0/2/0	Valo
Process Control	2/0/0	Fedorová, Oravec
Process Control I	2/0/0	Fedorová, Oravec
Programming I	2/0/2	Wadinger
Semestral Project I	0/0/3	Holaza, Klaučo, Kvasnica, Oravec

Team Project	0/0/4	Bakaráč, Oravec
Web Technologies II	1/0/3	Čirka
5th semester (Winter)		
Optimization	2/0/2	Horváthová
Presentation skills II	0/2/0	Klaučo
6th semester (Summer)		
Process Control II	2/0/2	Klaučo, Fedorová
Programming II	1/2/0	Kohút

5.2 Master Study

1st semester (Winter)		
Automatic Control Theory I	2/0/3	Fikar, Galčíková
Industrial Control Systems	0/0/2	Kalúz
Information Technology I	0/0/2	Holaza
Modelling in Process Industry	2/2/0	Paulen, Fáber
Optimisation of Processes and Plants	2/0/2	Kvasnica, Fedorová
Process Dynamics and Control	2/0/1	Holaza, Oravec, Fedorová
Programming of Web Applications I	1/0/2	Čirka
Technical Means of Automation I	2/0/2	Kalúz, Bakaráč, Dzurková, Furka
2nd semester (Summer)		
Automatic Control Theory II	2/0/3	Fikar, Holaza
Identification	2/0/2	Paulen, Mojto
Technical Means of Automation II	1/0/3	Kalúz, Dzurková, Valo
3rd semester (Winter)		
Automatic Control Theory III	2/0/2	Fikar, Pavlovičová
Batch data processing	1/3/0	Kvasnica, Wadinger
Creation of Scientific Documents	0/2/0	Holaza
Information Technologies II	0/0/2	Vargan
Process Control Project	0/0/3	Bakaráč, Oravec
Programming of Web Applications II	2/0/2	Čirka, Klaučo
Project Software Systems	0/2/0	Oravec

4th semester (Summer)

Intelligent Control	1/2/0	Kvasnica, Kohút, Wadinger
Predictive Control	1/2/0	Klaučo, Kiš
Robust Control	1/2/0	Oravec, Pavlovičová

5.3 PhD Study

Winter

Modelling and Control of Chemical Processes	2/0/3	Oravec
Advanced Predictive Control	2/3/0	Kvasnica
Selected Topics in the Theory of Automatic Control	2/0/3	Fikar

Summer

Modelling and Control of Biotechnological Processes	2/0/3	Paulen
Optimal Control	2/0/3	Fikar
Selected Topics in Intelligent Control	2/0/3	Oravec

5.4 Course Contents

5.4.1 Lectures in Bachelor Study

Process Control Seminar (2h/week, 1st semester) Introduction to process control. Basic terms – controlled process and its dynamics. Basic terms – sensors and actuators. Basic terms – regulator and constraints. Overview of hardware and software implementation of control systems. Overview of advanced control methods. Success stories – chemical industries. Success stories – food industries. Success stories – paper industries. Success stories – automotive. Success stories – robotics. Success stories – building control.

Dynamic Systems (2h/week, 2nd semester) Definition of a system. Definition of a dynamic system. Definition of a static system. Definitions of inputs, outputs and states of a dynamic system. Mathematical representation of dynamic systems. Types of mathematical models of dynamic systems. State space. Order of a dynamic system. Applications of mathematical representation of dynamic systems. Basic definitions from control of dynamic systems. Linearity, autonomy, causality and time invariance of dynamic systems. Equilibrium state of a dynamic system. Stability of equilibrium state of a dynamic system. Behaviour of a system in the neighbourhood of an equilibrium state. Stability of a dynamic system. Applications of dynamic system properties for monitoring and control of systems. Applications of control of dynamic systems.

Computer-based Simulation (1h/week, 3rd semester) The course is divided into two main parts. The first part is devoted to the study of methods for numerical solution of algebraic equations with emphasis on the identification of steady states of dynamical systems. The second part deals with the study of methods for the numerical solution of ordinary differential equations with main stress on the properties of dynamical systems.

Introduction. Types of mathematical models and their computer representation. Steady states of linear dynamical systems and their numerical identification. Steady states of nonlinear dynamical systems and their numerical identification. Steady states of nonlinear dynamical systems and their numerical identification – Newton's method. Steady states of nonlinear dynamical systems – multidimensional systems and multiple steady states. Introduction to ordinary differential equations. Analytical solution. Numerical solution of ordinary differential equations. Explicit Euler's method. Implicit Euler's method. Runge-Kutta methods. Implicit methods. Adams method. Collocation methods.

Modelling of Processes in Chemical and Food Technology (2h/week, 3rd semester) Introduction to process modeling, approaches to modeling, types of mathematical models. Nonlinear state-space model, linear state-space model, transfer function. Static and dynamic mathematical models of basic types of chemical and food technology processes: tanks for liquid storage, blenders, jacketed heat exchangers, flow heaters, recuperative heat exchangers, continuous stirred tank chemical reactors. MATLAB and Simulink software and its use for creating a nonlinear and linear process model, calculation and plotting of static process characteristics, simulation of transient characteristics of storage tanks, heat exchangers and chemical reactors using nonlinear and linear models. Evaluation and comparison of static and dynamic properties of processes.

Web Technologies I (1h/week, 3rd semester) The course is focused on development of web pages and it is divided into four main parts. First three parts are dedicated to technologies HTML, CSS and JavaScript, which are the main languages used for definition of content, design, and functionality of web pages. The last part is dedicated to production of complex web pages using the content management system Wordpress.

Logic Control (2h/week, 4th semester) The course is divided into three parts. The first one is dedicated to design of a logic control using finite-state machines (FSM) and its practical implementation in Stateflow. Second part is focused on programmable logic controllers (PLC) that represent a standard for control of machines and processes in manufacturing industries. In the last part, students will work on a selected laboratory project.

Process Control I (2h/week, 4th semester) Laplace transform. Transfer function and transfer functions of complex systems. Step response. Poles and zeros. Modelling of tanks. PID controller. Feed-back control loop and stability. Reference tracking and disturbance rejection. Control performance. Analytical methods for controller synthesis. Experimental methods for controller synthesis. Sensors and measurement of the controlled variables. Technological schemes with measurement and control loops.

Web Technologies II (1h/week, 4th semester) This course is devoted to the design of web-based information systems, and is divided intro three main parts. The first part is devoted to programming in PHP language with the connection to MySQL programming. During the second part, modern PHP frameworks are taught. The third part covers the fronted design in JavaScript, HTML and CSS. By completing this course, students are capable to combine all three mentioned software programming tools and they are capable of building standalone web-based application.

Optimization (2h/week, 5th semester) This course introduces basic mathematical formulations of optimizations tasks, ranging from simple ones (without any constraints), up to complex ones (with equality and inequality constraints); explains which algorithms are available to solve particular types of optimization problems; and introduces how the optimal solution is to be interpreted from an economic perspective.

Parameter Estimation (1h/week, 5th semester) The course is divided into two main parts. The first part introduces into basic and advanced concepts of statistical parameter estimation. Second part concentrates on parameter estimation for dynamic systems.

Database Systems (1h/week, 6th semester) The course is divided into three parts. The first part is focused on databases and data modeling in general. The second part forms the core of the course. It deals with the SQL language. The third part is practically oriented. In this part, students work in MySQL and MS Access databases.

Introduction, motivation and basic concepts of database systems. Data modeling (Conceptual model, Logical model, Physical model). Database normalization. SQL language (DDL, DML, Constraints, Views, Functions). MySQL (phpMyAdmin, Tables, Queries). MS Access (Tables, Forms, Queries, Reports, VBA). Non-relational database systems (NoSQL).

Introduction to Optimal and Predictive Control (1h/week, 6th semester) The subject is divided into three main parts. The first is devoted to the introduction of optimal control and basic mathematical formulations of optimal control problems. The second part describes the mathematical foundations of formulating predictive control problems as convex optimization problems. The last part deals with the applications of individual applications of optimal control strategies in industry and to practical examples.

Process Control II (2h/week, 6th semester) Process identification from aperiodic or periodic step response. Process identification from astatic step response. Methods for PID controller tuning. Quality criteria. 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 blenders, control of heat exchangers, control of pipelines, control of chemical reactors, control of biochemical reactors, control of neutralization processes. Actuators.

5.4.2 Laboratory Exercises in Bachelor Study

Electrical Engineering (2h/week, 1st semester) Basic knowledge about electric circuits and their individual components and how to use various methods to analyze and validate electric circuits. Overview of the principles of transmitting information (signals) via electric circuits. Basic signal processing and conditioning and integration of sensors into control systems. Practical skill in soldering, reading and understanding datasheets, and compiling technical documentation for electric circuits.

Tools of Technical Computing I (2h/week, 1st semester) This course continuously goes through the basic principles of computing and programming in MATLAB. Students will learn how to use the tool, define and use variables, data types, expressions, operators, functions, how to work with graphics, polynomials, symbolic expressions, and how to create custom applications.

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

Embedded Systems I (2h/week, 2nd semester) The course is divided into three parts. First part is focused on understanding the basic working principles of microcontroller platforms, electric circuits for sensing and control of physical processes, and getting acquainted with programming tools. Second part is practically oriented. In this part, students implement and program typical applications on microcontrollers. In the first two parts, students will also learn the basics of programming in C language. Third part is dedicated to individual projects, their presentation and defense.

Informatics I (2h/week, 2nd semester) Computer architecture. Layered architecture and structure of folders. Functionality and architecture of laboratory management information systems. Spreadsheet MS Excel. Address space organization of MS Excel, mathematical and statistical functions. Structured constructions, data analysis methods, charts, matrices and equation solving. Text editor MS Word, formatting and styles. Chemical and

mathematical texts, tables. Advanced functions and academic writing. Presentation and visualization, graphical and presentation software.

Introduction to the R Language (2h/week, 2nd semester) The R environment, related software and documentation, R and statistics. Simple manipulations & numbers and vectors: vectors and assignment, vector arithmetic, logical vectors, character vectors, index vectors. Objects and attributes: arrays and matrices, array indexing, index matrices. Lists and data frames: constructing and modifying lists, making data frames, working with data frames. Reading data from files: loading data from other R packages editing data. Writing your own functions: simple examples, more advanced examples. Recursive numerical integration, graphics, shiny server.

Tools of Technical Computing II (2h/week, 2nd semester) Orientation in the user interface of the MATLAB/Simulink environment. Search in the model library and its using. Advanced using of the model library. Configuration of the simulation environment and solver. The basic construction of the simulation schemes and their notation. Evaluation of exam no.1. Construction of the complex simulation schemes. Conditions in simulation schemes. Creating subsystems and their notation. Creating user-defined blocks. Editing of the masks of the blocks. Export of the constructed simulation schemes. Evaluation of exam no.2.

Computer-based Simulation (1h/week, 3rd semester) The curriculum of exercises follows the topics of lectures of this course.

Embedded Systems II (3h/week, 3rd semester) The course is divided into four parts. First part is focused on understanding advanced working principles of microcontroller platforms. The second part is dedicated to utilization of microcontrollers on the Internet of Things, with focus on standard architectures, communication interfaces, protocols, databases, and Cloud solutions. Third part is practically oriented. In this part, students implement typical microcontroller applications for the Internet of Things. Fourth part is dedicated to individual projects, their presentation and defense.

Informatics II (2h/week, 3rd semester) Automated task processing, scripting languages in Linux and Windows operating systems. Batch document creation and treatment. Typesetting using LaTeX (introduction, document classes, simple and mathematical environments, graphics, links, bibliography). Foundations of versioning systems.

Modelling of Processes in Chemical and Food Technology (2h/week, 3rd semester) The curriculum of exercises follows the topics of lectures of this course.

Operating Systems I (2h/week, 3rd semester) The course is divided into three main parts. The first is devoted to the basics of work in UNIX-type operating systems, as well as working with files and directories, archiving, searching, processing text files and remote computers. The second part is dedicated to the connection, installation, configuration and administration of your own UNIX-type system on a designated HW platform. The last part is focused on versioning tools such as GitHub.

Tools of Technical Computing III (2h/week, 3rd semester) This course offers practical experience with basics of data science (random variables, correlation analysis), machine learning (supervised and unsupervised learning) and creation of graphical user interfaces in the MATLAB environment. These three domains constitute the main parts of the course.

Random variables. Statistical probability distribution. Basic calculations of statistical analysis – average, median, moving average and median. Advanced calculations of statistical analysis – correlation, covariance matrix, correlation matrix. Methods of unsupervised machine learning. Principal component analysis. Data filtering. Linear regression. Nonlinear regression. Artificial neural networks. Deep artificial neural networks. Introduction to graphical user interface. Creating own applications using a graphical user interface.

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

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

Operating Systems II (2h/week, 4th semester) The course is divided into two main parts. The first is devoted to the syntax and application of basic elements of algorithms such as variables, conditions and cycles. The second is devoted to the design of algorithms and their implementation in the form of scripts

Presentation Skills I (2h/week, 4th semester) The course is divided into 3 main parts. In the first part of the course, students did acquire knowledge from the preparation and export of graphs in the Matlab environment for the needs of presentations. The second part is devoted to the preparation of a typographically sound document in MS Word and a presentation in MS PowerPoint. By completing this part, students gained knowledge of how to use styles, write equations and create tables. In the third part of the course, students will gain knowledge from the preparation of presentations in the MS PowerPoint environment. By the end of the course, students performed presentations rehearsals before the audience to develop presentation and soft skills.

Process Control I (2h/week, 4th semester) MATLAB programming environment. Solving Differential equations using Laplace transform – different real roots. Solving Differential equations using Laplace transform – multiple real roots. Transfer functions algebra. System properties – poles and zeroes. Model of liquid tanks. Closed-loop system stability. Control performance. Control of liquid tanks – analytical methods for controller design. Control of the selected system – experimental identification and controller tuning.

Team Project (4h/week, 4th semester) Assignment of the topic of the team project in the field of automation and informatization in chemistry and food industry. Selection of the optimal composition of the team while considering strengths and weaknesses. Selection of a suitable software platform for project planning and checking of plan fulfilment. Selection of a software platform for team collaboration (shared calendars, shared disk drives, wikis, etc.). Literature review and study of the field of the project. Group consultations on

the topic of the project. Problem analysis, team-based problem solving, written and oral presentation of the results obtained in solving the problem.

Assignment of the topic of the team project. Selection of the optimal composition of the team. Selection of software platforms and tools for collaboration. Literature survey and problem study. Consultations on the topic of the project. Problem analysis. Team-based problem solving. Written and oral presentation of the results.

Web Technologies II (3h/week, 4th semester) The curriculum of exercises follows the topics of lectures of this course.

Data Structures and Algorithms (2h/week, 5th semester) The course introduces fundamentals basic data structures that are used in efficient algorithms, shows the concept of modular arithmetics that is often used in cryptography, discusses divide-and-conquer algorithms, sorting methods, Fourier transform, Huffman encoding, algorithms for efficient searching in graphs, as well as quantum algorithms.

Distributed Version Control System (2h/week, 5th semester) The framework of the distributed version control. Software tools for distributed version control. Basic repository configuration. Advanced repository configuration. User interface configuration. Configuration of the users' access. Basic file management. Advanced file management. Team project focused on file management. Basic commit management. Advanced commit management. Team project focused on commit management.

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

Parameter Estimation (1h/week, 5th semester) The curriculum of exercises follows the topics of lectures of this course.

Presentation Skills II (2h/week, 5th semester) The course is divided into 3 parts. In the first part of the course, students acquired knowledge from the preparation of typographically perfect documents in the LaTeX environment. The second part is devoted to the preparation of a typographically high-quality presentation and posters in the LaTeX environment. By completing this part, students gained knowledge of creating documents, generating PDF outputs from the LaTeX environment, as well as working with tables and graphs in vector format. In the third part of the course, students will gain knowledge of the preparation of infographics and diagrams in a vector graphics editor (eg Inkscape). Students learned to work with basic vector structures, their placements and export to a vector format. Students learned to integrate their workflow between Matlab, a graphical editor and the LaTeX environment. In this course, students performed oral presentations with discussion in front of the audience to improve their presentation and soft skills.

Database Systems (3h/week, 6th semester) The curriculum of exercises follows the topics of lectures of this course.

Process Control Project (4h/week, 6th semester) Assigning the roles in the team, designing the project agenda, and time management of the particular tasks. Literature review on the selected process and considered control method. Model design. Model validation. Controller design. Simulation of the closed-loop control. Setting up the laboratory plant. Measurement of experimental results on laboratory plant. Controller tuning. Analysis of the control performance. Data processing and formulation of conclusions. Creating the presentation of the results.

Production of Audiovisual Works (2h/week, 4th semester) The course is focused on production of audiovisual works, specifically the video, audio, and photography. First two parts are dedicated to mastering the fundamental terms and principles of video, audio, and photo equipment operation (performed on practical examples). In the third (main) part of course, the students are assigned into teams and they work on production of audiovisual materials. In this part, the students master techniques of scene and screenplay preparation, video shooting, digital post-production and publishing of videos. This part also includes the photo shooting and photo editing.

Programming I (2h/week, 4th semester) This course introduces fundamentals of the Python programming language, demonstrates its internal data types, shows how to manipulate data using functions and methods, explains different ways in which users can interact with the program, shows how external files can be accessed, and how external modules and libraries can be utilized.

Spreadsheet and Database Systems for Data Processing (2h/week, 4th semester) Introduction to relational databases: What is a database? Why to use a database? MS Access and MySQL databases. Database design: Database normalization (1NF, 2NF, 3NF). Table creation (fields, data types, indexes, field properties, update). Forms and their elements: Form creation. Form controls configuration. Form formatting. Queries: Basic queries creation. Data sorting and filtration in a query. Calculations in a query. Basics of SQL. Reports: Report creation. Adding controls to a report. Report formatting. Simple practical application using database. MS Excel: Data processing function. Pivot tables and pivot charts. Macros.

Programming II (2h/week, 5th semester) This course introduces advanced aspects of Python programming, which include, but are not limited to: exceptions, functions to manipulate objects of the operating system, functions of the numpy library for technical computing, functions of the matplotlib library for data visualization, and functions of the scipy library for scientific computing.

Semestral Project (3h/week, 5th semester) Assignment of the topic of a semester project. Literature survey and problem study. Consultations on the topic of the project. Problem analysis. Independent problem solving. Written and oral presentation of the results.

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.

Industrial Technologies (2h/week, 6th semester) The course is divided into two main parts. The first part is devoted to an overview of technologies used in individual layers of the automation pyramid. The second is devoted to the implementation of the acquired knowledge on various experiments.

Introduction to Machine Learning (2h/week, 6th semester) The course is divided into 4 parts. The first part is focused on data processing, formatting and analysis of the datasets. The second part is dedicated to the introduction and implementation of some machine learning models. The third part is dedicated to the introduction and implementation of artificial neural networks with basic and complex formulations. The last part is dedicated to final group projects, where the theoretical and practical skills gained from previous parts are applied.

Introduction to Optimal and Predictive control (1h/week, 6th semester) The curriculum of exercises follows the topics of lectures of this course.

Introduction to the Julia Language (2h/week, 6th semester) This course introduces fundamentals of the Julia programming language, demonstrates its internal data types, shows how to manipulate data using functions and methods, explains different ways in which users can interact with the program, shows how external files can be accessed, and how external modules and libraries can be utilized.

Optimization of Processes and Plants (2h/week, 1st 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.

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

5.4.3 Lectures in Master Study

Automatic Control Theory I (2h/week, 1st semester) Modelling, (non)linear dynamical systems. State-space process models. Transfer functions of systems. Time response of linear systems. Frequency analysis. Closed-loop system. Root-locus. PID controllers, tuning.

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.

Programming of Web Application I (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 I (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) State-space representations, state-feedback control, state observers. Z-transform. Discrete-time dynamic systems. Properties of discrete-time dynamic systems. Control design for discrete-time systems.

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.

Technical Means of Automation II (1h/week, 2nd semester) The course is divided into four main parts. The first is dedicated to industrial standards for information interchange. In this part, students will get acquainted with flowcharts and process diagrams, their design, interpretation, and practical use. The second part provides a basic overview about architectures and working of distributed control systems (DCS), SCADA systems for monitoring and control of geographically large plants, and types of industrial networks. The third part deals with the applications of programmable logic controllers (PLC) Siemens SIMATIC. This part contains advanced PLC programming techniques, design and implementation of control algorithms, and operator screen design. The last part is dedicated to the final project, in which the student will design a control and monitoring system for a real laboratory plant.

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).

Batch Data Processing (1h/week, 3rd semester) The CSV format. Processing of CSV data in Matlab. Processing of CSV data in Python. Processing of CSV data in JavaScript. The JSON format. Processing of JSON data in Matlab. Processing of JSON data in Python. Processing of JSON data in JavaScript. The XML format. Processing of XML data in Matlab. Processing of XML data in Python. Processing of XML data in JavaScript. Validation and transformation of XML data using DTD, XML schema, and XSLT.

Programming of Web Applications II (2h/week, 3rd semester) PHP framework installation and setup, Database installation and setup, Database design, Object-oriented programming, MVC architecture, Form and validation, Authorization and authentication, Internationalization and localization, Framework and JavaScript, Document generation (PDF, XLSX, ...), Creating a simple application

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.

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

Programming of Web Application I (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 I (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.

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.

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

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

Batch Data Processing (3h/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.

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.

Programming of Web Applications II (2h/week, 3rd semester) The curriculum of exercises follows the topics of lectures of this course.

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 Thesis (20h/week, 4th semester) Specification of the thesis topic. Study of the available literature and processing of sources from the literature. The choice of the theoretical approach and methodology to solving the problem and planning experiments. Conducting of experiments and critical evaluation of obtained results. Writing of the final thesis. Defence of the diploma thesis.

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 Information Engineering and Process Control orients to advanced control theory and modelling of chemical and biochemical processes. Current research areas, among other research fields, include optimization, machine learning, model predictive control, robust control, etc.

6.1 Main Research Areas

Control Engineering Education (M. Fikar, Ľ. Čirka, M. Kalúz, J. Oravec, P. Bakaráč) 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.

Distributed and Decentralized Optimization (M. Kvasnica, J. Oravec, K. Fedorová, R. Kohút, E. Pavlovičová, 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.

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.

Guaranteed Parameter Estimation (R. Paulen, M. Mojto) 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.

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

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.

Modelling and Control of Chemical Reactors, Biochemical Reactors, Distillation Columns and Heat Exchangers (Ľ. Čirka, M. Fikar, A. Mészáros) The research of all research groups is focused on modelling and control of various types of chemical and biochemical processes.

Model Predictive Control (M. Kvasnica, M. Klaučo, J. Oravec, J. Holaza, P. Bakaráč, M. Furka, M. Horváthová, K. Fedorová, R. Kohút, L. Galčíková) Model Predictive control (MPC) has been successful not only in academia but in industrial process applications as well. Its main drawbacks are the stability problems. Development of new methods for explicit model predictive control. In this approach, the optimal solution to the given MPC problem is obtained for all admissible initial conditions by employing parametric programming methods. The resulting optimal feedback law is then represented by a look-up table, which allows for real-time implementation of MPC to processes with rapid sampling.

Optimal Control Design (M. Fikar) The main aim of this area is to develop a package of algorithms and program implementation of various known control design for a given plant. The research interests include single input-single output systems as well as multivariable dynamic systems. Control design covers strategies in discrete-time and continuous-time formulation. A program package is created in Matlab and Simulink environment.

6.2 International Scientific Projects

6.2.1 Twinning 101079342 – Fostering Opportunities Towards Slovak Excellence in Advanced Control for Smart Industries (M. Fikar)

Period: 2022 – 2025

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (M. Fikar – coordinator), Faculty of Electrical and Information Engineering (F. Duchoň, D. Rosinová), Faculty of Mechanical Engineering (M. Gulan), Faculty of Materials Science and Technology in Trnava (M. Strémy)
- Ruhr-Universität Bochum, Department of Automatic Control and Systems Theory, Faculty of Mechanical Engineering (research group of M. Mönnigmann)
- Universita Di Pisa, Department of Civil and Industrial Engineering (research group of G. Pannocchia)

The project aims at increasing the research and academic prospects of Slovak University of Technology in Bratislava, Slovakia (STUBA) and at initiating the evolution of STUBA into a modern, reputed excellent institution that performs high-quality research in advanced automatic control, educates top-quality scholars and industrial practitioners, and is successful in active dissemination and exploitation of its research and innovation efforts. For this purpose, STUBA teams up with two renowned research groups in automatic control from RU Bochum, Germany (RUB) and Pisa University, Italy (UNIPI). The specific goals of the action are to reinforce the collaboration with the two research groups from Western Europe, to intensify research in advanced automatic control, to open up new collaboration channels through academic and industrial networking, to train excellent young/senior researchers and project managers, and to effectively disseminate and exploit the research results of STUBA. The unique features of the project are:

- Adoption/amendment of internal research project-related rules and procedures and develop project management toolbox,
- Research efforts aiming at the continued creation of high-quality research results and software tools,
- Establishment of a series of guest scientific and academic lectures,
- Exchanges and training of project managers and research (junior and senior) personnel,
- Organisation of conferences and invited sessions, seminars with industry, and annual summer schools,
- Preparation and implementation of a new PhD curriculum at STUBA,
- Establishment of an academic-industrial research and innovation cluster.

6.2.2 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 APVV-21-0019 Data Based Process Control (M. Fikar)

Period: 2022 – 2025

The main aim of the proposed research project is to investigate and design new data-driven advanced methods of automatic control and monitoring in process industries to improve efficiency of process plants, their monitoring, and process control and to improve profitability, stability, and competitiveness. We will focus on processes with heat and mass transfer where efficiency can be improved significantly. These processes are inherently complex, exhibit nonlinear and hybrid behaviour that has consequences in control quality and performance. Optimal control and monitoring will cover interplay of techniques of applied statistics, treatment of big data, data-based state estimation, inferential sensors, dynamic optimisation, predictive control. Also, important will be software implementation of proposed solutions, available to a larger community in open-source code as well as verification of the proposed methods in laboratory conditions and with data from industrial partners.

6.3.2 APVV-20-0261: Energy-efficient Safe and Secure Process Control (M. Kvasnica)

Period: 2021 – 2024

The proposed project will develop novel approaches to the design of industrial process control systems with four unique features:

- Energy efficiency of the operated plants via advanced control;
- Guaranteed safety of the control loop with a certifiable satisfaction of safety requirements;
- Security of the closed loop against attacks from outside and from inside; and
- Applicability on existing process control hardware without the need of costly upgrades.

The main aim of the project is to develop a systematic and universal design procedure that will yield safe and secure control systems in new applications (so-called greenfield setups),

as well as for existing setups (so-called retrofits). This will open the door to industrial applications that will benefit from most progressive techniques for improving the safety, security, and economic performance in process industries.

6.3.3 VEGA 1/0490/23: Economically Efficient Predictive Control of Microgrids (M. Kvasnica)

Period: 2023 – 2026

The content of the project, which falls into the scientific field of automation, is basic research in the development of a comprehensive concept of design, synthesis and implementation of an automated system for cost-effective management of local power systems (microgrids) where own consumption is partially or completely covered by own production sources (often renewable energy sources such as solar panels and wind turbines), supplemented by energy storage systems and rotating assets. The proposed system will ensure the optimal utilization of individual assets so that the economy of operation is maximized and adverse effects on the environment are minimized. The main advantage of the proposed solution compared to the existing approaches is the integrity and conceptuality of the entire system, where the individual modules communicate with each other and increase the economic profitability of the entire system through a synergistic effect.

6.3.4 VEGA 1/0297/22: Controller Design Methods for Low-Level Carbon Footprint Process Automation (J. Oravec)

Period: 2022 – 2025

The project aims to develop advanced controller design methods for low-level carbon footprint process automation. Decreased energy consumption is achieved by implementing the advanced methods of model predictive control. These methods are based on the robust control approach, parallel computing, machine learning, and economic criteria. The model predictive control methods will be designed considering the requirements of the chemical, biochemical, pharmaceutical, and food industries. However, the implementation range will not be limited just to these fields of industry. The theoretical results of the project will be implemented and experimentally analyzed using laboratory devices. The practical aspects of implementation on standard industrial hardware will be considered to design the advanced control methods for low-level carbon footprint process automation.

6.3.5 VEGA 1/0691/21: Efficient Control of Industrial Plants Using Data (R. Paulen)

Period: 2021 – 2024

The project is focused in driving the industrial chemical plants towards effective use of resources and energy. Effective plant management will be reached as a synergy of tools for production planning and for advanced automatic feedback control. The technology enabling the reaching of these goals is based on the use of data a) for creation of input-output data-based models or of first-principles models with corrective data-based terms and b) for reliable monitoring of unmeasured process variables. The improved mathematical models are subsequently used for optimization of steady-state operating regimes and for optimization-based control of industrial plants. The designed algorithms and control structures are tested in simulations as well as in laboratory conditions. The project also stimulates cooperation with industry.

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

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.

6.3.7 Program to Support Excellent Teams of Young Researchers: Design of Optimal Controllers for Industrial Microprocessors (M. Horváthová)

Period: 2021 – 2023

This project deals with the design and implementation of advanced control methods on embedded microprocessor platforms used in the industry. In order to explore the possibilities of wider industrial implementation of the given advanced control methods. The methods are based on optimization and are able to certify the safety of the operation. Furthermore, the given methods can take into account the requirements for control performance and constraints for controlled and manipulated variables, which leads to an increase in the quality of production, and to a reduction in operating costs and negative impacts on the environment. The implementation of the given methods on embedded platforms is also in accordance with the concept of Industry 4.0. Selected advanced control methods implementable on embedded microprocessor platforms are:

- robust control based on convex lifting
- explicit model predictive control
- predictive control based on neural networks

The control performance of the given methods will be analysed and compared by means of various laboratory equipment, considering the embedded platforms. Selected equipment is:

- laboratory plate heat exchanger
- laboratory chemical reactor
- laboratory air conditioning-heating unit (from the English heating, ventilation, and air conditioning HVAC system)

These plants represent important parts of operations from various industries from chemical and pharmaceutical to manufacturing industry. And the implementation of advanced control methods considering embedded platforms would have the potential to significantly contribute to the development of the industrial operation.

6.3.8 Young Researcher: Optimization of Mathematical Model for an Industrial Distillation Column (M. Mojto)

Period: 2022 – 2023

Currently, distillation columns are an essential part of chemical technology, and their importance lies in the separation of liquid mixtures. The industrial application of distillation columns is significant mainly in oil refineries, where they are used to obtain the required oil products in the oil processing process. The quality of the distillation products depends on the efficiency of the distillation column. To increase the efficiency of these devices, it is necessary to have sufficient knowledge of the behavior of the distillation process as well as of the thermodynamic properties of the separated mixture. This knowledge can be acquired by taking the necessary tests. However, it is usually not possible to perform these tests directly on an industrial distillation column due to possible economic and safety reasons. Therefore, in this project we want to focus on building a faithful mathematical model (digital twin) for a specific industrial distillation column (depropanizer). Currently, many programs (Aspen HYSYS, UniSim Design, and others) are available for modeling chemical-technological processes. In this project, we will use the gPROMS ModelBuilder software for modeling. When modeling, we will be based on the relevant technical documentation and also on the measured data on the depropanizer. The derived mathematical model will then be subjected to an in-depth analysis with the aim of identifying the optimal operating mode for the depropanizer. The obtained results from this project will be presented at the conference Slovak Society of Chemical Engineeting (SSCHE) 2023. Subsequently, the obtained results and feedback from the SSCHE conference will be summarized in a journal publication. The created mathematical model will then be available to other students. In addition, our industrial partner Slovnaft, a.s., Bratislava, Slovakia, also showed great interest in this mathematical model. In order to facilitate access to that model, we will create detailed documentation for it with a description of all parts of the model.

6.3.9 Young Researcher: Secure Measurement Processing in the Chemical Industry (M. Furka)

Period: 2023

With advancing techniques of sensor creation and data processing, the number of options for attacking such networks is also increasing. Often, sensitive data communicated within the network can be leaked due to industrial espionage, etc. if an attacker got into the communication network and had access to the measuring or control members, he could very easily put the process out of operation and thereby devalue the resulting product. For this reason, it is important to ensure communication between individual elements. One possibility is to use classic encryption algorithms, which, using algorithms and mathematical relationships, transform the original message into a form unreadable by the attacker. However, it is often required to process these messages (data) in some way (eg calculate the average). In this case, it is necessary that each element of the sensor network has a key available. In other words, hacking any element of the network will allow access to all data. The solution to such a problem is the use of the so-called homomorphic encryption algorithms, which can perform mathematical operations on encrypted data using homomorphism. These algorithms make it possible to process data without the need to decrypt it. The goal of the project will be to use homomorphic encryption algorithms to secure data during communication and their processing within the sensory network of a

chemical process and thus secure the process itself against possible attacks, or industrial espionage.

6.3.10 Young Researcher: Computationally Effective Optimal Control of Plants in Chemical Industry (L. Galčíková)

Period: 2023

The effort to optimize the control of industrial processes is expanding more and more. The motivation is mainly saving operating costs, the energy load of the given device, or also increasing the quality of control. One of the methods based on optimization is predictive control. The main characteristic is the possibility of implementing the optimal value of the control input in each control step. Another feature is the possibility to include limits on manipulated or controlled variables, which is significant in the context of control of chemical-technological processes. It is thus possible to observe process limitations, safety and control stability. Predictive control also offers the possibility of increasing the quality of control, or saving energy and consumption of the control medium. The disadvantage of predictive control is the need to solve an optimization problem, which represents a demanding calculation process. However, the majority of control units used in industrial practice do not have the computing capacity suitable for solving the optimization problem. The goal of this project is to devote to the modification of predictive control so that it is suitable for implementation in practice on a much larger scale. The first step is to find a method that simplifies the predictive control solution. Another task is to validate the proposed complexity reduction method. Subsequently, I would like to publish my results at an international conference and in a scientific journal.

6.3.11 Young Researcher: Process Control Using Artificial Intelligence Methods (K. Kiš)

Period: 2022 – 2023

Control of chemical and biotechnological processes is one of the current topics in the field of automation. These processes are an essential part of both the food and technological industries. The main goal of this project is to design a controller that is based on the connection of predictive control and artificial intelligence. Predictive control is based on the calculation of optimal action interventions. Neural networks, as one of the main approaches of artificial intelligence, accelerate the calculation time of optimization algorithms. By combining both methods, we are able to get an optimal action intervention with reduced computing time. From the point of view of the control of chemical and biotechnological processes, this has the effect of energy and raw material efficiency even with limited possibilities of computing capacity. The process of training neural networks itself is a trivial matter. However, if we want to achieve the necessary quality of the controller, it is necessary to guarantee stability. As possible solutions, we are considering the use of the so-called tube MPC, which falls under robust control principles. In our case, the uncertainty is included in the worst deviation between the neural network and the MPC. We can guarantee stability and satisfaction of the constraints for the control designed in this way.

6.4 Operating Programs

6.4.1 HRS4R 003STU-2-1/2021: Acquisition of the HR Excellence in Research Award – HRS4R na STU (J. Oravec)

Period: 2021 – 2023

The implementation of the project will help STU to obtain the HR Excellence in Research Award and eliminate weaknesses identified by GAP analysis with regard to improving working conditions and professional development opportunities for researchers, creating more attractive conditions for researchers to stay in or new ones decided for STU.
In this project, UIAM solves particular tasks focused primarily on increasing the quality of e-learning support, including further development and updating e-learning courses, increasing soft skills, and upskilling of students and teachers.

6.4.2 EU-COVID-2021: Research in SMART Monitoring and Disease Prevention Against Coronavirus (SARS-CoV-2) (M. Klaučo)

Period: 2021 – 2023

The project is primarily focused on the development of a SMART system capable of detecting the possible return or outbreaks of COVID-19 in the population of the Slovak Republic based on wastewater analysis (the possibilities of the most accurate determination of outbreaks in individual cities will also be explored). In the next part, the project focuses on the development of micro-sensors designed for rapid detection of the virus (in wastewater and also in biological samples (saliva, skin or urine) in potentially infected.The project also focuses on the development and testing of innovative degradation and decontamination procedures and technologies (development of treatment technology, especially wastewater from point sources such as medical facilities, technologies modifying the process of drinking water treatment, antiviral materials based on selected polymers and modification of nanofibers to produce protective suits) capable of preventively protecting not only the civilian population but also technology or equipment using state security forces (decontamination of statutes or technology based on non-chlorinated oxidizing agents). In the framework of water purification and decontamination, new types of sorption materials based on carbon and silicon, selected nanomaterials and their modifications, membrane technologies and green oxidizing agents or their possible combinations will be investigated.

6.5 Cooperations

6.5.1 SK-FR-22-0003: Fr-Sk Cooperation: Smart Process Modelling, Optimisation, and Control (M. Fikar)

Period: 2023 – 2025

Partners:

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (M. Fikar, R. Paulen, M. Mojto, R. Fáber, J. Vargan)
- Institut National Polytechnique de Lorraine (INPL) - Ecole Nationale Supérieure des Industries Chimiques (ENSIC) (M. A. Latifi, F. Lesage, S. Elmisaoui, L. Sergent)

This research project deals with smart modelling, optimisation, and control in the chemical industry. These will be performed based on industrial process data, while also addressing advanced design of experiments and models incorporating uncertainties and reliability. We will propose data-oriented optimal control for these models. The newly developed methods and procedures will be verified on laboratory processes and will be presented to industrial partners for implementation.

7 Cooperations

7.1 International Cooperations

- Department of Process Control, Faculty of Electrical Engineering and Informatics, University of Pardubice, Pardubice, Czech Republic (Control System Design)
- Institute of Mathematics, Informatics, and Cybernetics, University of Chemistry and Technology Prague, 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)
- 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)
- Shanghai Tech University, China (Distributed Optimization, Model Predictive Control)
- École Polytechnique Fédérale de Lausanne, Switzerland (Distributed Optimization, Model Predictive Control)
- Department of Civil and Industrial Engineering, University of Pisa, Italy (Chemical Process Control)
- Department of Mechanical Systems Engineering, Faculty of Engineering, Shinshu University, Nagano, Japan (Process Control)

7.2 Cooperations in Slovakia

- Institute of Automotive Mechatronics, Institute of Robotics and Cybernetics, Faculty of Electrical Engineering and Informatics, Slovak University of Technology in Bratislava
- Institute of Automation, Informatization, and Measurement, 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, Inc., Actemium Slovakia, Šaľa
- Slovnaft, Inc., Bratislava

- NCHZ, Inc., Nováky
- Yokogawa Slovakia, Inc., Bratislava

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)
- Czechoslovakia Section of IEEE – Control Systems Society Chapter (M. Klaučo)
- European Federation of Chemical Engineers, working party on CAPE (M. Fikar)

7.4 Membership in Domestic Organizations and Societies

- Slovak Society for Cybernetics and Informatics (M. Fikar, A. Mészáros, J. Mikleš)
- Slovak Society of Chemical Engineering (M. Fikar, J. Mikleš, A. Mészáros, R. Paulen)
- Learned Society of Slovakia (M. Fikar)

8 Theses and Dissertations

8.1 Bachelor Theses (B.Sc. degree)

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

D. Bazarkhanova	Microservice Architecture for Streaming Data Processing (Kvasnica, M.)
B. Daráš	Model Predictive Control Design for a Prototype of Smart Greenhouse (Oravec, J.)
V. Koncserová	Automation and Control of Process Data Streams (Kvasnica, M.)
M. Krivošík	Intelligent Data Processing (Klaučo, M.)
K. Kruhliak	Modeling and Process Control Design in the gPROMS ModelBuilder Environment (Paulen, R.)

8.2 Master Theses (M.Sc. degree)

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

P. Belková	Tunable Explicit Model Predictive Control Design (Oravec, J.)
M. Bognár	Design and Implementation of a Smart Sensor on Embedded Platforms (Bakaráč, P.)
M. Bujdáková	Data-based Input-output System Identification (Paulen, R.)
M. Hatvanyi	Design and Implementation of Web Based on Laravel Framework – Modules for Pedagogy (Čirka, Ľ.)
M. Holub	Realization of a Low-cost Data Collection System with Focusing on Water Treatment Area Usage (Valo, R.)
K. Kvasnicová	Robust Model Predictive Control Design for a Plate Heat Exchanger (Oravec, J.)
T. Mészárosová	Advanced Control of a Laboratory Distillation Column (Paulen, R.)
Z. Mošková	Optimization of RFID Chip Placement in a Tire (Paulen, R.)
M. Špaková	Intelligent Automatic Greenhouse (Valo, R.)
P. Valábek	Generation of Explicit Control Laws with Reinforcement Learning (Klaučo, M.)
J. Vargan	Optimality Analysis of MPC Controller (Fikar, M.)

S. Záhorčák	Microservices for Processing of Streamed Data (Kvasnica, M.)

8.3 PhD's Theses (PhD. Degree)

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

M. Horváthová	Energy-Efficient Advanced Robust Control Design (Oravec, J.)
M. Mojto	Data-driven Design of Linear Soft Sensors (Paulen, R.)

9 Publications

9.1 Book

1. J. Oravec: *Distributed Version Control System Git (in Slovak)*, 2023.

9.2 Articles in Journals

1. N. Alygizakis – K. Ng – N. Maragou – S. Alirai – P. A. Behnisch – H. Besselink – P. Oswald – Ľ. Čirka – N. S. Thomaidis – J. Slobodník: Battery of In Vitro Bioassays: A Case Study for the Cost-Effective and Effect-Based Evaluation of Wastewater Effluent Quality. *Water*, 2023. DOI

2. R. Dyrska – M. Horváthová – P. Bakaráč – M. Mönnigmann – J. Oravec: Heat exchanger control using model predictive control with constraint removal. *Applied Thermal Engineering*, 2023. DOI Zenodo

3. M. Furka – M. Kalúz – M. Fikar – M. Klaučo: Guidelines for Secure Process Control: Harnessing the Power of Homomorphic Encryption and State Feedback Control. *IEEE ACCESS*, 2023. DOI Zenodo

4. R. Mitze – M. Kvasnica – M. Mönnigmann: Exploiting symmetries in active set enumeration for constrained linear–quadratic optimal control. *Automatica*, pp. 1 – 8, 2023. DOI

5. M. Mojto – K. Lubušký – M. Fikar – R. Paulen: Data-Based Design of Multi-Model Inferential Sensors. *Computers & Chemical Engineering*, 2023. DOI arXiv Zenodo

6. K. Ng – N. Alygizakis – M. Nika – A. Galani – P. Oswald – M. Oswaldova – Ľ. Čirka – U. Kunkel – A. Macherius – M. Sengl – G. Mariani – S. Tavazzi – H. Skejo – B. M. Gawlik – N. S. Thomaidis – J. Slobodník: Wide-scope target screening characterization of legacy and emerging contaminants in the Danube River Basin by liquid and gas chromatography coupled with high-resolution mass spectrometry. *Water Research*, 2023. DOI

9.3 Articles in Conference Proceedings

1. T. Ábelová – K. Fedorová – M. Kvasnica: Optimization-Based Power Distribution Method for State-of-Charge Balancing of Battery Storage Systems. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, 2023.

2. T. Ábelová – R. Kohút – K. Fedorová – M. Kvasnica: Risk-Aware Stochastic Energy Management of Microgrid with Battery Storage and Renewables. In *IFAC World Congress 2023, Yokohama, Japan*, 2023. Zenodo

3. Ľ. Čirka – M. Kalúz: Educational Device FlexyAir in Teaching of Process Control. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, pp. 33 – 33, 2023.

4. R. Dyrska – J. Müller – M. Fikar – M. Mönnigmann: Simple Controller Tuning for Unmanned Aerial Vehicles using Governors. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 2023 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, pp. 108 – 113, 2023. Zenodo

5. R. Fáber – K. Ľubušký – M. Mojto – R. Paulen: Enhancing Industrial Data Analysis through Machine Learning-based Classification of Petrochemical Datasets. In *49th International Conference of the Slovak Society of Chemical Engineering SSCHE 2023*, Slovak Society of Chemical Engineering, Bratislava, SK, pp. 160 – 160, 2023. Zenodo

6. R. Fáber – K. Ľubušký – R. Paulen: Machine Learning-based Classification of Online Industrial Datasets. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 2023 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, 2023. DOI Zenodo

7. K. Fedorová – T. Ábelová – M. Kvasnica: Dynamic Power Purchase Agreement. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 2023 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, 2023.

8. K. Fedorová – Y. Jiang – J. Oravec – C. N. Jones – M. Kvasnica: A Generalized Stopping Criterion for Real-Time MPC with Guaranteed Stability. In *62nd IEEE Conference on Decision and Control*, Marina Bay Sands, Singapore, 2023.

9. M. Fikar – K. Kiš – M. Klaučo – M. Mönnigmann: Simple Tuning of Arbitrary Controllers using Governors. In *IFAC World Congress 2023, Yokohama, Japan*, pp. 9109 – 9114, 2023. Zenodo Youtube

10. M. Furka – J. Holaza – M. Klaučo: Towards Fully Homomorphic Explicit Model Predictive Control via Polynomial Approximation. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, 2023.

11. L. Galčíková – P. Belková – J. Oravec: Real-time tuning of approximated explicit MPC of a heat exchanger. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, pp. 38 – 38, 2023. Zenodo

12. J. Holaza – L. Galčíková – J. Oravec – M. Kvasnica: A software package for MPC design and tuning: MPT+. In *62nd IEEE Conference on Decision and Control*, Marina Bay Sands, Singapore, 2023.

13. J. Holaza – K. Kvasnicová – E. Pavlovičová – J. Oravec: Tube MPC Extension of MPT: Experimental Analysis. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 2023 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, pp. 120 – 125, 2023. Zenodo

14. M. Horváthová – L. Galčíková – M. Klaučo – J. Oravec: Real-Time Optimisation-Based Robust Control: Heat Exchanger Comparative Analysis. In *62nd IEEE Conference on Decision and Control*, Marina Bay Sands, Singapore, 2023.

15. M. Horváthová – J. Oravec: Approximated Convex-lifting-based Robust Control for a Heat Exchanger. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, 2023. Zenodo

16. M. Kalúz – R. Kohút – D. Dzurková: MPC-Mimicking Neural Network Based on Homomorphic Encryption. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 2023 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, pp. 126 – 131, 2023. Zenodo

17. K. Kiš – M. Klaučo: Nearly-optimal Explicit MPC-based Reference Governors with Long Prediction Horizons Generated with Machine Learning. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, 2023.

18. R. Kohút – M. Kvasnica: Power Output Reconstruction of Photovoltaic Curtailment. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 2023 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, 2023.

19. R. Kohút – E. Pavlovičová – K. Fedorová – J. Oravec – M. Kvasnica: Real-Time Deep-Learning-Driven Parallel MPC. In *62nd IEEE Conference on Decision and Control*, Marina Bay Sands, Singapore, 2023.

20. M. Mojto – K. Ľubušký – M. Fikar – R. Paulen: Comparing Linear and Nonlinear Soft Sensor Approaches for Industrial Distillation Columns (in Anglo-Saxon). In *49th International Conference of the Slovak Society of Chemical Engineering SSCHE 2023*, Slovak Society of Chemical Engineering, Bratislava, SK, pp. 159 – 159, 2023. Zenodo

21. M. Mojto – K. Ľubušký – M. Fikar – R. Paulen: Input Structure Selection for Soft-Sensor Design: Does It Pay Off?. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 2023 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, pp. 162 – 167, 2023. Zenodo

22. M. Mojto – K. Ľubušký – M. Fikar – R. Paulen: Data-Driven Indication of Flooding in an Industrial Debutanizer Column. Editor(s): Antonis Kokossis, Michael C. Georgiadis, Efstratios N. Pistikopoulos, In *33rd European Symposium on Computer Aided Process Engineering*, Elsevier, no. 1, vol. 33, pp. 1001 – 1006, 2023. DOI Zenodo

23. M. Mojto – K. Ľubušký – M. Fikar – R. Paulen: Design of Multi-Model Linear Inferential Sensors with SVM-based Switching Logic. In *IFAC World Congress 2023, Yokohama, Japan*, pp. 2545 – 2550, 2023. Zenodo Youtube

24. J. Oravec – P. Bakaráč – E. Pavlovičová – M. Fikar: Smart Eco Greenhouse VESNA. In *IFAC World Congress 2023, Yokohama, Japan*, pp. 10295 – 10300, 2023. Zenodo

25. E. Pavlovičová – J. Oravec: Distributed Model Predictive Control Design for a Laboratory Device. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, pp. 50 – 50, 2023. Zenodo

26. M. Ružička – I. Helgeland – R. Paulen: Modelling of a Forward Osmosis Process (in Slovak). In *Membránové procesy pro udržitelný rozvoj – MEMPUR 2023*, pp. 35 – 36, 2023.

27. P. Valábek – M. Klaučo: Generation of MPC-like Explicit Control Laws with Reinforcement Machine Learning. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, 2023.

28. J. Vargan – J. Puk – K. Ľubuský – M. Fikar: Steady-State Analysis of Industrial MPC Controllers. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control – Summaries Volume*, Slovak Chemical Library, Slovak University of Technology in Bratislava, Radlinského 9, SK812-37, Bratislava, Slovakia, 2023. Zenodo

29. M. Wadinger – M. Kvasnica: Real-Time Outlier Detection with Dynamic Process Limits. Editor(s): R. Paulen and M. Fikar, In *Proceedings of the 24th International Conference on Process Control*, IEEE, Slovak University of Technology in Bratislava, Radlinského 9, 81237, Bratislava, Slovakia, 2023. arXiv

10 Research Seminars

10.1 Research Seminar on Smart Cybernetics

Feb, 2 Y. A. W. Shardt (Ilmenau University of Technology): Soft Sensors: Applications and Rumination

Feb, 17 S. Leonow (Ruhr University Bochum): Collaborative Control under Strict Security Requirements on Lean Embedded Hardware,

R. Bacci di Capaci, M. Vacari (University of Pisa): Acid Gas Treatment in Waste-to-energy Plants: a Case Study of System Identification and Advanced Control

Mar, 3 R. Dyrska (Ruhr University Bochum): Simple Controller Tuning for Unmanned Aerial Vehicles using Governors

Mar, 10 G. Pannocchia (University of Pisa): Systems Identification Algorithms and Software Tools for the Application of MPC in Process Control Systems

Mar, 17 M. Mojto: Multi-fidelity Modeling with Gaussian Process Model

Mar, 24 A. Vargová, J. Boldocký: AutomationShield: An Open-Source Hardware and Software Initiative for Control Engineering Education

Mar, 31 M. Klaučo: Active Set Prediction using Machine Learning for the Complexity Reduction in Nonlinear Model Predictive Control

Apr, 14 B. R.-Iľkiv: Spline-based Continuous-time MPC

Apr, 21 B. Kvasnica: Challenges and Opportunities in Forecasting, Optimization, and Monetization of Renewable Energy

Apr, 28 Ľ. Horanská: Nonadditive Integrals as a Tool for Aggregation

May, 5 M. Furka: Comprehensive Analysis of Modern Cryptographic Schemes for Secured Process Control

May, 12 M. Horváthová: Deep-Learning-Driven Tunable MPC with Stability Guarantees

May, 19 P. Jičinský (University of Pardubice): Motion Analysis Tool for Orthopedic Diseases

May, 26 J. Oravec, J. Holaza: Tube MPC Extension of MPT

Jun, 13 P. Kittisupakorn, S. Singcuna (Chulalongkorn University): Use of PLC for Sequential Control Applications

Aug, 22 M. Mönnigmann (Ruhr University Bochum): Teaching 'Recursive Stability' of MPC to Engineering Students

Sep, 19 R. Bacci Di Capaci (University of Pisa): A System Identification Package for Python: Actual Features and Future Developments

Oct, 6 L. Galčíková: Tube Model Predictive Control

Oct, 12 A. Bemporad (IMT School for Advanced Studies, Lucca): Learning-based Methods for Model Predictive Control (online, Pisa)

M. E. Villanueva (IMT School for Advanced Studies, Lucca): Set-Based Computing in Robust Control: A Polytopic Approach (online, Pisa)

Oct, 20 C. de Prada Moraga (University of Valladolid): Developing Grey-box Process Models

Oct, 27 R. Kohút: Do Sequences Matter? Application for Carbon Emission Prediction of the Electricity Grid

Nov, 3 A. Maidi (Mouloud Mammeri University): Globally Linearizing Control of Distributed Parameter Systems Described by Time-fractional Partial Differential Equations

Nov, 9 R. Bacci Di Capaci (University of Pisa): Valve Stiction and MPC: A Long Sticky and Freaky Journey

Nov, 10 K. Fedorová: Real-time Parallelizable MPC using Spatio-temporal Splitting

Nov, 14 S. Leonow (Ruhr University Bochum): Embedded Implementation of a Neural Network Controller Emulating Nonlinear MPC in a Process Control Application

Nov, 24 R. Dyrska (Ruhr University Bochum): An Introduction to Unmanned Aerial Vehicles

10.2 Other Seminars

Mar, 23 M. Fikar: How to Write Successful MSCA IF Proposal (seminar took place at University of Regensburg)

Mar, 20 R. Fáber: Machine Learning-Based Classification of Industrial Datasets (seminar took place at University of Pisa)

Mar, 22 R. Paulen: Optimal Control of Batch Membrane Processes (seminar took place at University of Pisa)

Mar, 24 R. Paulen: Introduction to Optimization (seminar took place at University of Pisa)

Jul, 7 J. Oravec: Tube Model Predictive Control: Current Challenges and Perspectives (seminar took place at Shinshu University)

Jul, 7 E. Pavlovičová: Real-Time Deep-Learning-Driven Parallel Model Predictive Control (seminar took place at Shinshu University)

Nov, 8 M. Klaučo: Machine Learning Methods for Active Set Prediction: Accelerating NMPC Computation (seminar took place at Ruhr University Bochum)

11 International Visits

11.1 Visits at our Department

• Jan, 30–Feb, 22	Y. Shardt	Ilmenau University of Technology, Germany
• Feb, 27–Mar, 3	R. Dyrska	Ruhr University Bochum, Germany
• Mar, 7–11	G. Pannocchia	University of Pisa, Italy
• May, 15–Jun, 14	P. Jičinský	University of Pardubice, Czech Republic
• Jun, 2–Jun, 14	S. Singcuna, P. Kittisupakorn	Chulalongkorn University, Thailand
• Aug, 17–21	Y. Shardt	Ilmenau University of Technology, Germany
• Sep, 18–24	R. B. Di Capaci	University of Pisa, Italy
• Oct, 18–22	C. de Prada Moraga	University of Valladolid, Spain
• Oct, 25–Nov, 11	A. Maidi	Mouloud Mammeri University, Algeria
• Nov, 5–10	R. B. Di Capaci	University of Pisa, Italy
• Nov, 13–17	S. Leonow	Ruhr University Bochum, Germany
• Nov, 13–24	R. Dyrska	Ruhr University Bochum, Germany

11.2 Visits from our Department

Participation at Conferences

• May, 15–18	R. Fáber, M. Mojto, R. Paulen	Slovak Society of Chemical Engineering SSCHE 2023, Tatranské Matliare, Slovakia
• Jun, 17–22	M. Fikar, M. Mojto, R. Paulen	European Symposium on Computer-Aided Process Engineering (ESCAPE-33), Athens, Greece
• Jul, 7–21	T. Ábelová, P. Bakaráč, K. Fedorová, M. Fikar, M. Horváthová, K. Kiš, M. Klaučo, R. Kohút, M. Mojto, J. Oravec, R. Paulen, E. Pavlovičová	International Federation of Automatic Control (IFAC), Yokohama, Japan
• Jun, 16–21	M. Fikar, M. Mojto, R. Paulen	European Symposium on Computer-Aided Process Engineering (ESCAPE-33), Athens, Greece
• Dec, 10–17	K. Fedorová, L. Galčíková, J. Holaza, M. Klaučo, R. Kohút	Conference on Decision and Control (CDC), Singapore

International Cooperation

• Sep, 7–9	M. Fikar	Principia Cybernetika, Ostrava, Czech Republic

Research Stays

• Mar, 18–25	R. Fáber, R. Paulen	Pisa, Italy
• Jun, 19–23	P. Bakaráč	Ilmenau, Germany
• Jul, 5–7	M. Horváthová, J. Oravec, E. Pavlovičová	Nagano, Japan
• Oct, 5–10	R. Paulen	Bochum, Germany
• Nov, 7–9	M. Klaučo	Bochum, Germany
• Nov, 26–Dec, 1	M. Fikar, J. Vargan	Nancy, France

Summer School

• Jun, 26–30	T. Ábelová, E. Pavlovičová, M. Wadinger	International Graduate School on Control (IGSC) in European Embedded Control Institute (EECI), Zurich, Switzerland

12 Miscellaneous

12.1 Organisation of International Conferences

- Process Control 2023 (Jun, 6–9) (IPC: R. Paulen, M. Fikar; NOC: M. Klaučo, J. Oravec)

12.2 Summer School

- FrontSeat Summer School on Embedded Optimal Control (Sep, 11–15)

12.3 Workshops

- Marie Skłodowska-Curie Actions: Doctoral Networks, Advanced Materials & Processes and Artificial Intelligence for Sustainability (Mar, 22–23)
- WANT-ED: Workshop on Advanced Technologies in Education (May, 22–24)
- Scientific event between Bayer and STUBA (Sep, 22)
- Functional Safety Workshop (Oct, 10)
- Educative workshop for students in University Center Litvínov, VŠCHT FS ČVUT, ORLEN Unipetrol (Oct, 17–21)

12.4 Awards

- doc. Ing. MSc. Martin Klaučo, PhD.
  - Laureate of the ESET Science Award 2023 (in the category Outstanding Personality of Science under the age of 35)
  - Award: Slovak Personality of Science and Technology under the age of 35 (Ministry of Education, Science, Research and Sport of the Slovak Republic)
- Ing. Michaela Horváthová, PhD.
  - STU Rector's Prize for excellent performance of study obligations throughout the post-graduate studies
- Ing. Petronela Belková
  - Thermo Fisher Scientific award for the outstanding master thesis
- Ing. Martina Bognár
  - Actemium award for the outstanding master thesis
- Ing. Martina Bujdáková
  - Dean's Prize for excellent results during the graduate studies and results achieved in the student scientific and technical activities
  - Humusoft award for the outstanding master thesis

- Ing. Patrik Valábek
  - STU Rector's Prize for excellent performance of study obligations throughout the graduate studies
  - Dean's Prize for excellent results during the graduate studies and results achieved in the student scientific and technical activities
  - Humusoft award for the outstanding master thesis
- Ing. Jozef Vargan
  - Dean's Prize for excellent results during the graduate studies and results achieved in the student scientific and technical activities
  - REPAR-Building Control award for the outstanding master thesis
- Ing. Samuel Záhorčák
  - Siemens award for the outstanding master thesis
- Bc. Matej Ružička
  - Commendation of the Director of IAM (September 18, 2023) for successful completion of an industrial internship in AQUAPORIN, Lyngby, Denmark and subsequent presentation of the achieved results at the conference in MEMPUR, Pardubice, Czech Republic

12.5 Other Events

- prof. Ing. Miroslav Fikar, DrSc.
  - Appointment to the position of director of Institute of Information Engineering, Automation, and Mathematics (2023–2027)
- doc. Ing. MSc. Martin Klaučo, PhD.
  - Appointment of Institute Deputy Director for Science and Research