SLOVAK UNIVERSITY OF TECHNOLOGY
IN BRATISLAVA

FACULTY OF CHEMICAL AND FOOD
TECHNOLOGY

INSTITUTE OF INFORMATION ENGINEERING, AUTOMATION
AND MATHEMATICS

DEPARTMENT OF INFORMATION ENGINEERING AND PROCESS CONTROL

ANNUAL REPORT

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Address:

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Institute of Information Engineering, Automation and Mathematics

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From left: B. Takács, M. Jemelenský, K. Macušková, M. Kvasnica, J. Kmeťová, J. Holaza, J. Závacká, M. Kalúz, A. Vasičkaninová, Ľ. Čirka, A. Kalmárová, R. Valo, M. Karšaiová, J. Števek, S. Vagač, M. Klaučo, M. Fikar

Missing: M. Bakošová, S. Blažek, J. Drgoňa, A. Mészáros, J. Mikleš, J. Oravec, R. Paulen, A. Szűcs

Contents

1 Preface

Department of Information Engineering and Process Control has at the Faculty of Chemical and Food Technology of the Slovak University of Technology in Bratislava more than forty-year tradition. In the frame of the bachelor study program Information Engineering, Automation and Management in Chemical and Food Industry and the master study program Information Engineering and Automation in Chemical and Food Industry, it educates high-qualified specialists in the field of process control for design, implementation and processing of control systems.

Nowadays, information technologies and process control with using microprocessor based control technique represent important and acknowledged scientific branches. These branches more and more influence the economic and social growth in the whole world and successively also in Slovakia. The chemical, food and pharmaceutical industries with their technologies are no exceptions. No technology is able to be successful in the competition without optimization and advanced control systems or without using information technologies. In the connection with these facts, all our graduates have found their jobs without problems during the whole history of the department. It confirms also, that the education of the specialists in the information engineering and process control has been very attractive and its significance is even growing. The graduates of the department do well not only in the companies and institutions oriented on design and supplying of control systems for various technologies but also in the bank sector and they found their own firms respectively. Teaching and research activities of the department are oriented on process control, identification and modeling of systems, adaptive control, construction and testing of measuring devices and equipment, and on development of software packages for intelligent control systems. Second branch is devoted to information technologies, data management, and Internet programming.

prof. Ing. Miroslav Fikar, DrSc.

2 Introduction

This report summarizes the teaching and research activities at the Department of Information Engineering and Process Control at the Faculty of Chemical and Food Technology at the Slovak University of Technology in Bratislava during the period 1 January – 31 December 2013.

Department of Information Engineering and Process Control of the FCFT STU in Bratislava was constituted from the Department of Measuring and Control Technique of the Faculty of Electrical Engineering of the Slovak University of Technology in Bratislava in 1962. Because of the specific control problems of the processes and systems in the chemical and biochemical technologies, the specialization Process Control in the frame of the study branch Chemical Engineering and Process Control has been established. Students and post-graduate students have been educated since 1964. So far, more than four hundreds specialists and almost thirty PhD students have been graduated here and three 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 Assoc. prof. Alojz Mészáros, PhD and prof. Ing. Miroslav Fikar, DrSc. has headed the department since 2003.

Department of Information Engineering and Process Control is one of the 22 departments at the FCFT STU, where students obtain specialization in various branches of chemical technology or chemical engineering. Approximately 1000 students are currently enrolled in the three-year bachelor programs leading to the Bc. degree and two-year master programs leading to the Ing. degree, which is equivalent to the MS degree. The best of them continue in the four-year doctor programs leading to the PhD degree. Three study programs are guaranteed by the Department of Information Engineering and Process Control: bachelor study program Automation, Information Engineering and Management in Chemical and Food Technologies, master study program Automation and Information Engineering in Chemical and Food Technologies and PhD study program Process Control.

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Neural Networks, Modeling and Control of Biochemical Processes

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Expert Systems, Fuzzy Control, Genetic Algorithms, Optimisation

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Model Predictive Control, Hybrid Systems

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	Predictive Control, Hybrid Systems, Optimisation

3.5 Researchers

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	Dynamic Optimization, Hybrid Processes, Global Optimization, Parameter Estimation

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Model Predictive Control, Mixed-Integer Optimization

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4 Teaching and Research Laboratories

Laboratory of Process Control:

- Distillation Column UOP3CC
- Multifunction Station Armfield PCT40
- Liquid Tanks DTS200, Training Station Armfield PCT23

Laboratory of Control Systems:

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

Laboratory of Industrial Technology:

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

Computer Laboratories:

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

Remote Laboratories: Control of technological processes via internet access

- Two-tank system
- Thermal-optical systems

5 Educational Activities

5.1 Bachelor Study

1st semester (autumn)		
Computer Based Data Processing	0/0/2	Drgoňa, Jelemenský, Karšaiová, Takács, Kmeťová
2nd semester (spring)		
Informatisation and Information Systems	1/2/0	Blažek, Čirka, Kalúz
Operating Systems	0/0/3	Valo
3th semester (autumn)		
Modelling	2/0/3	Oravec, Vasičkaninová, Závacká
4th semester (spring)		
Laboratory Exercises of Process Control	0/0/2	Karšaiová, Oravec, Vasičkaninová
Process Control	2/0/0	Bakošová
Optimisation	2/3/0	Dvoran, Števek
5th semester (autumn)		
Design of Information and Control Systems	2/3/0	Kvasnica, Valo
6th semester (spring)		
Process Control	2/0/0	Bakošová
Laboratory Exercises of Process Control	0/0/2	Karšaiová, Oravec, Števek, Vasičkaninová, Závacká
Integrated Control in Process Engineering	2/0/3	Bakošová, Karšaiová, Vasičkaninová

Informatisation and Information	1/2/0	Čirka
Laboratory Exercises in Informatisation and Information Systems	0/0/2	Kalúz
Bachelor Projects	0/0/9	Bakošová, Čirka, Dvoran, Fikar, Kalúz, Karšaiová, Kvasnica, Števek, Valo, Vasičkaninová, Závacká

5.2 Master Study

1st semester (autumn)		
Semestral Project I	0/0/3	Bakošová, Čirka, Fikar, Karšaiová, Kvasnica, Valo, Vasičkaninová
Programming of Network Application	1/0/2	Čirka
Technical Means of Automation	2/0/2	Juhás
Information Technologies I	1/1/	Čirka
Automatic Control Theory I	3/0/2	Fikar, Vasičkaninová
Modelling in Process Industries	2/0/2	Bakošová, Karšaiová, Oravec
Process Control and Dynamics	2/0/1	Bakošová, Karšaiová, Oravec
2nd semester (spring)		
Technological Process Control	1/1/0	Dvoran
Identification	2/0/2	Čirka, Fikar

Industrial Control and Information Systems I	2/0/1	Kvasnica, Valo
Automatic Control Theory II	3/0/2	Čirka, Fikar
Semestral Project II	0/0/3	Bakošová, Čirka, Fikar, Karšaiová, Kvasnica, Valo, Vasičkaninová
3rd semester (autumn)		
Automatic Control Theory III	2/0/3	Fikar, Závacká
Information Technologies II	1/1/0	Čirka
Industrial Control and Information Systems II	2/0/2	Holaza, Kvasnica
Optimization of Processing and Production	2/0/2	Klaučo, Kvasnica
Diploma Project	0/0/4	Bakošová, Čirka, Kalúz, Kvasnica, Valo, Vasičkaninová
4th semester (spring)		
Model Predictive Control	2/0/1	Kvasnica, Takács, Drgoňa
Intelligent Control	2/0/1	Dvoran
Robust Control	2/0/1	Bakošová
Diploma Thesis	0/0/17	Bakošová, Čirka, Fikar, Kvasnica, Valo, Vasičkaninová

5.3 PhD Study

Automatic Control Theory	4/0/0	Mikleš
Modelling and Control of Proceses in Chemical Technology	2/0/0	Bakošová
Optimal Control	2/0/0	Fikar
Intelligent Control	2/0/0	Dvoran

5.4 Course Contents

5.4.1 Lectures in Bachelor Study

Optimization (2h/week, 4th semester) Static optimization, classification of problems, goal functions, boundaries. Extrema without boundaries – analytical methods. Single-dimensional case, multi-dimensional case, Hess matrix. Conditions for extrema. Extrema with boundaries – linear boundaries, direct method, method of Lagrange multipliers. Extrema with boundaries – nonlinear boundaries, Kuhn – Tucker theorem. Non-gradient methods – Box-Wilson method, flexible simplex method, method of cyclic exchange of parameters. Gradient methods – Regula falsi method, Newton method, Broyden method, DFP method, PARTAN method. Convergence of gradient methods.

Modeling (2h/week, 3rd semester) Fundamentals of chemical process modeling and simulation. Linear and nonlinear state-space models. Mathematical models of selected chemical processes with lumped parameters. Nonlinear and linearized models of a tank and serially connected tanks. Linear and nonlinear models of mixing processes. Mathematical models of processes with heat transfer: recuperative heat exchanger, shell heat exchanger, flow heater. Nonlinear and linearized mathematical models of continuous stirred tank reactors. Dynamic and static behavior of processes.

Operating Systems (1h/week, 2nd semester) Introduction to operating systems of computers. Multitasking, types of multitasking and their comparison. Linux – operation system of UNIX-type, its installation. Free and Open Source Software, GNU Foundation. Introduction to Solaris operating system. Basic file and directory operations, editing, searching, regular expressions, makefiles. Introduction to computer typesetting. Remote computers, communication tools: telnet, ssh, ftp, http, smtp.

Process Control (2h/week, 4th and 6th semester) Introduction to process control. Modeling of special types of processes of chemical technology. Static and dynamic behavior of controlled systems. Closed loop for control of technological processes. Controllers. Dynamic behavior of closed loops. Stability of systems. Synthesis of controllers. Control of special types of processes of chemical technology. Basic principles of devices and methods for measurement of technological quantities.

Design of Information and Control Systems (2h/week, 5th semester) Basic principles and methods for control systems design concerning control aims requirements. Systematic design approach. Utilization of modern software and technical tools for control design. Information control supply.

Integrated Control in Process Engineering (2h/week, 6th semester) Feedback and feed-forward control. More complex control structures: cascade control, feed-forward-feedback control, control loop with auxiliary control input, time-delay compensator – Smith predictor, flow-ratio control, special cases of multi-variable control. Process control: control of storage tanks, control of mixing units, control of heat exchangers, control of distillation columns, control of chemical reactors, control of dryers.

Information and Information Systems
(1h/week, 2st and 6th semester) Information system, systems for data processing. Database system structure. Logic data organization methods, database architecture. Means of data defining and manipulation. SQL language. Visualization level of technological and production process control. SCADA/HMI (Supervising Control and Data Acquisition / Human Machine Interface) application design. Professional software packages and components (WinCC, dSPACE/Control Desk, MATLAB/MWS for Windows XP/2000/NT).

Creating HTML application and dynamic web pages bounded to control system databases, SCADA/HMI systems etc.

5.4.2 Lectures in Master Study

Programming of Network Application (1h/week, 1st semester) PHP language a SQL database systems basics. Internet programming. Process or other database sources data and measurement processing. Technical Means of Automation (2h/week, 1st semester) Continuous-time controllers, types and their static and dynamic behavior. Discrete controllers, their dynamic behavior and using in control loops. PC in the role of a controller. Servo-drives for electric and pneumatic control system. Control valves. Digital devices. Logic functions, electric devices for realization of logic functions. Sequence loops. Hardware for control of technological processes. Analogue input modules, A/D, D/A converters. Digital input modules. Sources of inaccuracies in control loops.

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

Automatic Control Theory I (2h/week, 1st semester) State-space process models. Stability, controllability, observability of continuous-time systems. Input-output process models. Lyapunov stability. Frequency analysis. Bode plot. Nyquist plot. Gain and phase margins. State feedback and state observers. Algebraic control design.

Process Control and Dynamics (2h/week, 1st semester) Introduction to control of technological processes. Principles of control of technological processes: feedback and feed-forward control. Simple feedback control loop. Methods for PID controller tuning. Complex control loops: time-delay compensation (Smith predictor), cascade control, feed-forward compensation of disturbances, flow-ratio control. Control of tanks, control and controlled vari-

ables. Control of heat exchangers, controlled and control variables, control loops. Control of distillation and absorption columns, controlled and control variables, control loops. Control of chemical reactors, controlled and control variables, control loops. Basic principles of devices and methods for measurement of technological quantities: liquid level, temperature, pressure, flow rate, concentration.

Information Technologies I (1h/week, 1st semester) Computer terminology. Basic hardware and software. Network protocols and architectures. Data security and protection. Design of static web pages. Basic structure of a web page. XHTML language – elementary tags and attributes. Cascade style sheet formatting.

Industrial Control and Information Systems I
(2h/week, 2nd semester) Basic principles and stages of industrial information system design. System reliability and diagnostics. Projecting and control design of selected technologies using an appropriate software. PLC systems and Profibus. WinCC visualization tools. Programming with use of ladder logic, state list, and function block diagrams.

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

Automatic Control Theory II (2h/week, 2nd semester) State-space discrete-time models. Input-output discrete-time models. Controllability and observability of discrete-time systems. Direct digital control. Stability of discrete-time systems. Discrete-time feedback systems. Optimal control and principle of minimum. LQ control. Dynamic programming. Optimal observers and state estimation. Kalman filter.

Information Technologies II (1h/week, 3rd semester) Syntax of PHP language and its applications. Program structure, data types, constants, string operations, logic operators. Control structures – conditions, if-then-else statement, loops. Connection with database – searching, selecting, updating, database functions, forms, control and data elements on the web page. An example of design of final web application for working with database.

Automatic Control Theory III (2h/week, 3rd semester) Adaptive Control: self-tuning and MRAC. Advanced process control: heat exchangers, distillation columns, waste-water treatment plants, crystallization, combustion, neutralization, chemical reactors. MIMO control: RGA, decoupling, MPC

Industrial Control and Information Systems II
(2h/week, 3rd semester) The aim of this course is to teach students to work with industry information systems. The principles and means of communication in the design of information and communication systems: XML, DTD, XML Schema, Xpath, XSLT, SVG.

Optimization of Processing and Production (2h/week, 3rd semester) Introduction to convex optimization, recognition of convex/concave functions. Basic properties of convex sets, hyperplanes, halfspaces, polyhedra and polytopes. Standard formulation of optimization problems, linear and quadratic optimization. Dual formulation, Lagrange function, Karush-Kuhn-Tucker conditions of optimality. Linear programming and its properties. Applications of convex optimization: geometric problems and separation. Numerical algorithms for solving optimization problems.

Model Predictive Control (2h/week, 4th semester) Introduction to principles of the predictive control, types of models and objective functions. Formulation of a problem as the optimization problem with aim to predictive control of the chemical technology systems. Introduction to predictive control and definition of the main terms. Explanation of the norms and their application in LP and QP problems. Construction of the optimization problems and their implementation in YALMIP. State-tracking, output tracking, predictive control with integrator and time-varying reference tracking. Explicit model predictive control.

Robust Control (2h/week, 4th semester) Introduction to the robust control and one-parametric uncertainties. Interval uncertainties, robust stability analysis of systems with interval uncertainties and Kharitonov Theorem. Synthesis of robust controllers for systems with interval uncertainties. Polytopic uncertainties, edges, analysis of robust stability for the polytopic systems and Edge Theorem. Multi-linear parametric uncertainties. Design of robust control for the systems with parametric uncertainties, simultaneous stabilization. Low gain theory, generalized Kharitonov Theorem.

Introduction to the LMI systems and robust controllers design using LMIs. Unstructured uncertainties and analysis of robust stability. Analysis methods of the robust stability for systems with unstructured uncertainty and analysis methods of the robust stability for system with unstructured uncertainties.

Intelligent Control (2h/week, 4th semester) Introduction to the artificial intelligence, recognition methods (attribute and structural). Problem solving, expert systems (diagnostic and planning). Fuzzy logic, fuzzy identification, modeling and control. Neural networks in identification and control. Neuro-fuzzy control and genetic algorithms in intelligent control.

5.4.3 Laboratory Exercises in Bachelor Study

Computer Based Data Processing (2h/week, 1st and 3rd semester) MATLAB/Simulink as a tool for system simulation, MATLAB – Control toolbox. Filtration of signals, analogue and digital filters, MATLAB – Signal processing toolbox. MS Excel as a tool for data processing. Data processing by tables, data visualization by graphs, analytical tools in MS Excel, statistics in MS Excel. Origin as a tool for data visualization and processing.

Optimization (3h/week, 4th semester) Extrema without boundaries – analytical methods. Single-dimensional case, multi-dimensional case. Extrema with boundaries – linear boundaries, direct method, method of Lagrange multipliers. Extrema with boundaries – nonlinear boundaries. Non-gradient methods – Box-Wilson method, flexible simplex method, method of cyclic exchange of parameters. Gradient methods – Regula falsi method, Newton method, Broyde method, DFP method, PARTAN method.

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

Laboratory Exercises of Information Engineering and Systems (1h/week, 6th semester) Introduction to information systems and technologies. Electronic computers, computer software and computer networks. Internet. Language XHTML a CSS. Installation and setting of the software for programming (Apache, PHP, MySQL). Principles of programming language PHP. Work with databases.

6 Current Research Activities

Research at the Department of Process Control is oriented to advanced control theory as so as to practical applications in control of processes of chemical technology.

6.1 Main Research Areas

Modeling and Simulation (M. Bakošová, M. Karšaiová, J. Mikleš) Modeling and simulation play an important role in the investigation of static and dynamic properties of chemical processes, units and systems. Most chemical systems are strongly non-linear and their simulation is necessary for the control design as well as for the investigation of the overall control systems. The main aim of the research is to develop program packages for modeling and simulation of various kinds of models. During the last year a package MODELTOOL for MATLAB/ Simulink was improved and its Internet module was created.

System Identification (Ľ. Čirka, M. Fikar, J. Mikleš) System identification deals with problem of the parameter estimation of static or dynamic systems from observed input-output data. Among many topics of system identification, the following areas have been investigated in this project:

- nonparametric methods, correlation and spectral analysis
- recursive identification of transfer functions of continuous-time systems, Z-transform discrete-time models and delta-transform discrete-time models
- identification in closed-loop

A program package IDTOOL has been developed for Simulink. This toolbox implements recursive LS algorithm LDDIF and provides blocks for continuous and discrete time parameter estimation.

Optimal Control Design (M. Fikar, J. Mikleš) 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 multi-variable dynamic systems. Control design covers strategies in discrete-time and continuous-time formulation. A program package is created in MATLAB and Simulink environment.

Adaptive Control (M. Bakošová, Ľ. Čirka, M. Fikar, A. Mészáros, J. Mikleš) Most of technological plants exhibit non-linear behavior. To apply a successful control design to practical problems is a substantial effort. The processes are known to be modeled and controlled with serious difficulties caused by their non-linear behavior, high order dynamics, and tendency to instability. Many of industrial processes must be considered as multi-variable systems. In a great deal of available control design techniques it is often necessary to carry out the steps of modeling, identification and control design. Theory and implementation of adaptive control in technological systems have been the long-time research topics. The activities in the adaptive control have been concentrated to three main areas as follows:

- self-tuning control – characterized by repeating parameter estimation and control design
- model reference adaptive control based on the Lyapunov method
- decentralized adaptive control

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

Model Predictive Control (M. Fikar, M. Kvasnica) 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. The aim of this research is to enhance the basic input-output predictive methods. The problem is solved by means of the Youla-Kučera parametrization of

all stabilizing controllers. Both finite and infinite horizon formulations are handled. Another approach is to assume that the loop is already controlled by a linear controller and to find the minimum number of control, or tracking error steps that leads to stable closed-loop behavior. In all cases, it can be shown that the minimum number of steps is closely related to the number of unstable poles/zeros of the plant. Another area of research is 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.

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

Modelling and Control of Chemical Reactors, Biochemical Reactors, Distillation Columns and Heat Exchangers (M. Bakošová, J. Dvoran, Ľ. Čirka, M. Fikar, M. Karšaiová, A. Mészáros, J. Mikleš, A. Vasičkaninová) The research of all research groups is focused on modelling and control of various types of chemical and biochemical processes. Control Engineering Education (M. Fikar, Ľ. Čirka, M. Bakošová) Research in this domain focuses on application of information technologies in control education. This covers interactive on-line blocks and automatic generation of testing problems. The current research involves personification of students problems.

Information Technologies (M. Fikar, Ľ. Čirka, M. Kvasnica) 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 GNU/Linux, FreeBSD, Solaris.

6.2 Research Projects in Slovak Republic

6.2.1 VEGA 1/0095/11: Model Predictive Control on Platforms with Limited Computational Resources (M. Kvasnica)

Period: 2011 – 2014

The project is aimed at conducting research in the area of real-time implementation of Model Predictive Control (MPC) using hardware control platforms with limited computational power and constrained memory storage. Such constraints are typical for a broad class of industrial control systems, including, but not limited to, digital signal processors of programmable logic controllers. Therefore the main focus of the project is to develop novel theoretical approaches aimed at reducing the computational demands of MPC implementation in real time and to provide unique software tools for design, analysis, verification and implementation of predictive controllers. The main goal is to achieve faster and cheaper implementation of MPC on industrial control systems. Results of the projects will be verified on a large number of real-life control systems and published in international journals.

6.2.2 VEGA 1/0973/12: Control of Processes with Uncertainties in Chemical Technology and Biotechnology (M. Bakošová)

Period: 2012 – 2015

The scientific project deals with development of advanced control methods for systems with uncertainties and focuses on processes typical in chemical and food technologies, as e.g. chemical reactors, biochemical reactors, distillation columns, heat exchangers and other energy consuming processes. Development of methods of robust stabilization and robust predictive control of systems with uncertainties constitutes the core of the project and the goal is to assure more efficient energy saving control in comparison to classical approaches. Computational requirements and practical use will be taken into account in

the design of control algorithms. Designed algorithms, controllers, and control structures will be tested by simulations and in laboratory conditions. They will be compared with classical ones from the viewpoint of energy consumption during the control.

6.2.3 VEGA 1/0053/13: Optimal Process Control (M. Fikar)

Period: 2013 – 2016

The main project aim is design of optimal operation of selected processes in chemical and food technologies. It will primarily focus on two process types: membrane filtration processes and polymerization reactors. For membrane processes, we will concentrate on fouling effects and on embedded membrane processes as a part of the overall technology. For polymerization reactors, we will study hybrid behavior corresponding to different stages during polymer production and we will propose effective control structures.

Theoretic results will be sought in study of global deterministic methods that are able to find not only a local solution but converge to a neighborhood of the global solution in a finite time. The aim is to design such methods and algorithms that will be usable for optimization of more detailed process models and for estimation of their parameters.

The obtained results will be implemented in open source software packages and available in Internet. The aim is a broader dissemination of results in optimal control and optimal parameter estimation in process technologies.

6.2.4 APVV-0551-11: Advanced and Effective Methods of Optimal Process Control (M. Fikar)

Period: 2012 – 2015

The project is focused on research and development of optimal control methods of nonlinear systems. Such systems are typical in chemical and biochemical technologies as separations, chemical reactors, waste-water treatment plants. The project will deal with design of advanced methods and control algorithms that will be more effective than the actual ones with respect to memory consumption and computational power. This will make possible to implement easier newly developed methods in industrial control systems. On the top layer, dynamic optimization will be used for qualitative analysis and as a generator of optimal trajectories. The suboptimal bottom layer represented by

MPC and robust controllers will approximate the desired optimal operation and we will study the degree of suboptimality of these approaches. Other goals include providing a user-friendly software implementation of such a two-tiered architecture accessible to typical control engineers, as well as validation of the proposed solutions on experimental devices.

6.3 Other Projects in Slovak Republic

6.3.1 027/2009/4.1/OPVaV: Support for Finalisation of Centre of Excellence for Smart Technologies, Systems, and Services II

Period: 2010 – 2013

- Slovak University of Technology in Bratislava: FEI STU, SjF STU, UIAM FCHPT STU (prof. Fikar), FIIT STU
- International laser centrum
- Institute of informatics, Slovak academy of sciences

Quality increase of top research and education teams in smart technologies, systems, and services and integration in international cooperation. Establishment of technical infrastructure for strategic projects and improvement of Slovakia in international projects. Improvement of effectiveness in know-how transfer know-how between academic and industrial sphere in smart technologies, systems, and services. Concentration of the best research groups and their integration to international cooperation in European research.

6.3.2 University Scientific Park STU Bratislava

Period: 2013 – 2015

Project aims:

- To strengthen cooperation in research and development between industrial and academic spheres by creating of university research part oriented to selected research fields
- To create and develop university research park STU Bratislava Applied research

- To support transfer of technologies and knowledge to praxis

6.4 International Scientific Programs

6.4.1 SK-FR-0004-11: Fr-Sk Cooperation Štefánik

Dynamic and Global Optimisation of Processes

Period: 2012 – 2013

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. Jelemenský, L. Petáková)
- Institut National Polytechnique de Lorraine (INPL) – Ecole Nationale Supérieure des Industries Chimiques (ENSIC) (M. A. Latifi, M. Daroux, F. Lesage)

This research project deals with unsteady-state operation of dynamic processes that are described by a detailed mathematical models, typically with non-linear ordinary differential equations. The optimization of performances of such processes consists in the determination of optimal profiles of decision variables (temperature, pressure, flow, heat, ...) or optimal parameter values of the dynamic model which optimize (minimize, maximize) a given performance index (time of operation, yield, energy consumption,...), over a time horizon, under specified constraints (safety, environment, process physical limits,...). This kind of problems are known as dynamic optimization (or open-loop optimal control). Some selected problems include determination of optimal control in batch processes, estimation of optimal kinetic parameters in chemical reactions based on experimental data, optimal input design for parameter estimation, determination of optimal control trajectory during set-point change, security analysis of processes, model based predictive control based on continuous model, etc.

7 Cooperations

7.1 Cooperations in Slovakia

- Institute of Robotics and Cybernetics, Faculty of Electrical Engineering and Informatics, Slovak University of Technology, Bratislava
- Institute of Automation, Measurement, and Applied Informatics, Faculty of Mechanical Engineering, Slovak University of Technology, Bratislava
- Institute of Automotive Mechatronics, Faculty of Electrical Engineering and Informatics, Slovak University of Technology, Bratislava
- Institute of Informatics, Slovak Academy of Sciences, Bratislava
- Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Košice
- Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Košice, Košice
- Slovnaft, Inc., Bratislava
- Invensys Systems (Slovakia) s.r.o., Bratislava

7.2 International Cooperations

- Department of Process Control and Computer Techniques, Faculty of Chemical Technology, University of Pardubice, Pardubice, Czech Republic (Control system design)
- Department of Computing and Control Engineering, Prague Institute of Chemical Technology, Prague, Czech Republic (Control system design)
- Faculty of Applied Informatics, Tomas Bata University, Zlín, Czech Republic (Adaptive control, robust control)
- Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic, Prague, Czech Republic (Polynomial synthesis, Model Predictive Control)
- Faculty of Electrical Engineering, Czech Technical University, Prague, Czech Republic (Model Predictive Control)

- LSGP-CNRS, Ecole Nationale Superieure des Industries Chimiques (ENSIC), Nancy, France (Dynamic optimisation and control)
- Ecole Nationale Superieure des Ingenieurs de Genie Chimique-Chemin de la Loge (ENSIGC), Toulouse, France (Neural networks, Learning automata, Model Predictive Control)
- Automatic Control Laboratory, ETH Zurich, Switzerland (Model Predictive Control, Modeling, analysis, and control of hybrid systems)
- University of Dortmund, Dortmund, Germany (Model Predictive Control)
- Technical University of Budapest, Budapest, Hungary (Modelling of chemical processes)
- University of Veszprem, Hungary (Environmental engineering, Bioengineering projects)
- Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College London, United Kingdom (Global optimization, Parameter estimation)

7.3 Membership in Domestic Organizations and Societies

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

7.4 Membership in International Organizations and Societies

- International Federation of Automatic Control, Laxenburg, Austria (M. Fikar)
- European Federation of Biotechnology, Brussels, Belgium (A. Mészáros)

- New York Academy of Sciences, New York, USA (A. Mészáros)
- European Union Control Association (M. Kvasnica)
- European Membrane Society (R. Paulen)

8 Theses and Dissertations

8.1 Bachelor Theses (BSc. degree)

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

D. Janočko	Exploitation Raspberry PI for education purposes Network Systems (R. Valo)
M. Kleščík	Flash Presentations in Course Informatics and Information Systems (Ľ. Čirka)
V. Kukla	Flash Presentation for Course Identification (Ľ. Čirka)
T. Miklovič	Visualization of Charge Density (M. Gall)
J. Minárik	Minimization of Piecewise Linear Functions (M. Kvasnica)
D. Pakšiová	Control of Thermo-optical Plant (J. Závacká)
B. Pinterová	Programming of NXT Robots (R. Valo)
J. Uhrinovský	Data Export from Information System of UIAM (Ľ. Čirka)

8.2 Master Theses (MSc. degree)

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

Baluch, A.	Controller Design for Unstable Systems (A. Vasičkaninová)
Bugárová, K.	Development of a Library of Technological Process Models (Ľ. Čirka)

Černá, K.	Development of the PIDDESIGN Software (M. Bakošová)
Jenčík, R.	Internet Module for Process Modelling and Simulation (L. Čirka)
Juriga, I.	Programming Unit for NC machine (R. Valo)
Klaučo, M.	MPC-Based Reference Governors (M. Kvasnica)
Malinič, J.	Internet Module for Process Modelling and Simulation (L. Čirka)
Mitterpach, B.	Implementation of Proxy Server on Department (M. Fikar)
Páleš, D.	Model Predictive Control of a Group of Cars (M. Kvasnica)
Paternain, D.	Static and Dynamic Optimization of Networked Systems (M. Kvasnica)
Peterková, K.	Robust PID Controller Design for Control of Non-minimum Phase Systems (M. Bakošová)
Švecová, M.	Using of Artificial Intelligence in Classification and Prediction tasks (M. Gall)

9 Publications

9.1 Chapters or Pages in Books

1. Bakošová, M. – Oravec, J.: Robust PDLF-based MPC of a Chemical Reactor, In Recenzovaný zborník vedeckých prác zo stretnutia katedier automatizácie, kybernetiky a informatiky technických vysokých škôl a univerzít v SR a ČR SKAKaI 2013, Editor(s): Pirník R., Holečko P., EDIS – vydavateľstvo Žilinskej univerzity v Žiline, pp. 1–6, 2013.

2. Bakošová, M. – Závacká, J. – Oravec, J.: Automation – an Integral Part of Production Processes in the Chemical and Food Industries and the Daily Life (in Slovak), In Chémia pre život, Slovenská chemická knižnica FChPT STU v Bratislave, Bratislava, pp. 90–101, 2013.

9.2 Articles in Journals

1. Bakošová, M. – Oravec, J.: Robust Model Predictive Control of Heat Exchanger Network. Chemical Engineering Transactions, no. 35, pp. 241–246, 2013.

2. Bakošová, M. – Oravec, J. – Matejičková, K.: Model Predictive Control-Based Robust Stabilization of a Chemical Reactor. **Chemical Papers**, no. 9, vol. 67, pp. 1146–1156, 2013.

3. Beccuti, A. – Kvasnica, M. – Papafotiou, G. – Morari, M.: A Decentralized Explicit Predictive Control Paradigm for Parallelized DC-DC Circuits. **IEEE Transactions on Control Systems Technology**, no. 1, vol. 21, pp. 136–148, 2013.

4. Kvasnica, M. – Hledík, J. – Rauová, I. – Fikar, M.: Complexity reduction of explicit model predictive control via separation. **Automatica**, no. 6, vol. 49, pp. 1776–1781, 2013.

5. Paulen, R. – Jelemenský, M. – Fikar, M. – Kovacs, Z.: Optimal balancing of temporal and buffer costs for ultrafiltration/diafiltration processes under limiting flux conditions. **Journal of Membrane Science**, vol. 444, pp. 87–95, 2013.

6. Podmajerský, M. – Fikar, M. – Chachuat, B.: Measurement-based optimization of batch and repetitive processes using an integrated two-layer architecture. **Journal of Process Control**, no. 7, vol. 23, pp. 943–955, 2013.

7. Vasičkaninová, A. – Bakošová, M.: Application of H2 and H∞ Approaches to the Robust Controller Design for a Heat Exchanger. Chemical Engineering Transactions, no. 35, pp. 463–468, 2013.

8. Vasičkaninová, A. – Bakošová, M.: Robust control of a chemical reactor with uncertainties. Acta Chimica Slovaca, no. 2, vol. 6, pp. 194–201, 2013.

9. Závacká, J. – Bakošová, M.: Design of Robust PI Controller for Counter-Current Tubular Heat Exchangers. Acta Chimica Slovaca, no. 2, vol. 6, pp. 235–239, 2013.

9.3 Articles in Conference Proceedings

1. Bakošová, M. – Oravec, J.: Robust MPC of a Chemical Reactor Using the Nominal System Optmization. Editor(s): Markoš, J., In Proceedings of the 40th International Conference of Slovak Society of Chemical Engineering, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 1070–1078, 2013.

2. Čirka, Ľ. – Kalúz, M. – Fikar, M.: New Features in Random Assignment – Module for LMS Moodle. In Zborník príspevkov z medzinárodnej vedeckej konferencie: Inovačný proces v e-learningu, Ekonóm, pp. 1–6, 2013.

3. Čirka, Ľ. – Kalúz, M. – Fikar, M.: Virtual Laboratories for Control Education. In Zborník príspevkov z medzinárodnej vedeckej konferencie: Inovačný proces v e-learningu, Ekonóm, pp. 1–5, 2013.

4. Čirka, Ľ. – Kalúz, M. – Fikar, M.: On-line Remote Control of MATLAB Simulations Based on Asynchronous Communication Model. Editor(s): Petr Byron, In 21th Annual Conference

5. Drgoňa, J. – Kvasnica, M.: Comparison of MPC Strategies for Building Control. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 401–406, 2013.

6. Drgoňa, J. – Kvasnica, M. – Klaučo, M. – Fikar, M.: Explicit Stochastic MPC Approach to Building Temperature Control. In IEEE Conference on Decision and Control, Florence, Italy, pp. 6440–6445, 2013.

7. Herceg, M. – Kvasnica, M. – Jones, C. – Morari, M.: Multi-Parametric Toolbox 3.0. In 2013 European Control Conference, pp. 502–510, 2013.

8. Holaza, J. – Takács, B. – Kvasnica, M.: Synthesis of Simple Explicit MPC Optimizers by Function Approximation. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 377–382, 2013.

9. Jelemenský, M. – Paulen, R. – Fikar, M. – Kovacs, Z.: Economically Optimal Batch Ultrafiltration with Diafiltration under Limiting Flux Conditions. In Desalination using membrane technology, Elsevier, no. 1, vol. 1, 2013.

10. Jelemenský, M. – Paulen, R. – Fikar, M. – Kovacs, Z.: Economically Optimal Diluant Addition for Batch Ultrafiltration/Diafiltration Processes. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 415–420, 2013.

11. Jelemenský, M. – Paulen, R. – Fikar, M. – Kovacs, Z.: Multi-objective optimal control of ultrafiltration/diafiltration processes. In Proceedings of the 12th European Control Conference, Zurich, Switzerland, pp. 3384–3389, 2013.

12. Jelemenský, M. – Paulen, R. – Fikar, M. – Kovacs, Z.: Economically Optimal Control of Batch Diafiltration Processes. In IEEE Multi-Conference on Systems and Control, Hyderabad, India, pp. 734–739, 2013.

13. Jelemenský, M. – Paulen, R. – Fikar, M. – Kovacs, Z.: Economically Optimal Water Utilization in Batch Ultrafiltration/Diafiltration Processes. In Permea 2013 – Proceedings of the 6th Membrane Conference of the Visegad Countries, pp. 27–27, 2013.

14. Kalúz, M. – Čirka, Ľ. – Fikar, M.: Simplifying the Implementation of Remote Laboratories in Educational Environments Using Industrial Hardware. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of

15. Kalúz, M. – García-Zubía, J. – Orduña, P. – Fikar, M. – Čirka, Ľ.: Sharing Control Laboratories by Remote Laboratory Management System WebLab-Deusto. Editor(s): Sebastián Dormido, In Proceedings of 10th IFAC Symposium on Advances in Control Education, International Federation of Automatic Control, Sheffield, UK, vol. 10, pp. 345–350, 2013.

16. Klaučo, M. – Poulsen, N. K. – Mirzaei, M. – Niemann, H. H.: Frequency Weighted Model Predictive Control of Wind Turbine. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 347–352, 2013.

17. Kmeťová, J. – Vasičkaninová, A. – Dvoran, J.: Neuro-fuzzy Control of the Continuous Stirred-tank Reactor. Editor(s): Markoš, J., In Proceedings of the 40th International Conference of Slovak Society of Chemical Engineering, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 1107–1116, 2013.

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20. Matejičková, K. – Bakošová, M.: Robust PI controller desing for a time-delay process. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 480–485, 2013.

21. Oravec, J. – Bakošová, M.: The Control Performance Evaluation of the Selected On-line Robust MPC Approaches. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 152–158, 2013.

22. Oravec, J. – Blažek, S. – Kvasnica, M.: Simplification of Explicit MPC Solutions via Inner and Outer Approximations. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on

Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 389–394, 2013.

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24. Oravec, J. – Blažek, S. – Kvasnica, M. – Di Cairano, S.: Polygonic Representation of Explicit Model Predictive Control. In IEEE Conference on Decision and Control, Florence, Italy, pp. 6422–6427, 2013.

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26. Paulen, R. – Benyahia, B. – Latifi, M. A. – Fikar, M.: Optimal feeding of emulsion polymerization reactor for styrene and butyl acrylate copolymerization. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 427–432, 2013.

27. Paulen, R. – Villanueva, M. – Chachuat, B.: Optimization-Based Domain Reduction in Guaranteed Parameter Estimation of Nonlinear Dynamic Systems. Editor(s): Tarbouriech, Sophie; Krstic, Miroslav, In 9th IFAC Symposium on Nonlinear Control Systems, International Federation of Automatic Control, pp. 564–569, 2013.

28. Paulen, R. – Villanueva, M. – Fikar, M. – Chachuat, B.: Guaranteed Parameter Estimation in Nonlinear Dynamic Systems using Improved Bounding Techniques. In Proceedings of the 12th European Control Conference, Zurich, Switzerland, pp. 4514–4519, 2013.

29. Števek, J. – Kvasnica, M. – Fikar, M.: Towards a dominant-polytope complexity reduction in Explicit MPC. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 124–129, 2013.

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32. Vasičkaninová, A. – Bakošová, M. – Karšaiová, M. – Kmeťová, J.: Methods for Controller Tuning for Unstable Systems. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 208–213, 2013.

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35. Závacká, J. – Bakošová, M. – Matejičková, K.: Robust PI controller design for a continuous stirred tank reactor with multiple steady-states. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 19th International Conference on Process Control, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 468–473, 2013.