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: A. Sharma, D. Ingole, R. Valo, A. Mészáros, M. Klaučo, M. Kvasnica, A. Vasičkaninová, Ľ. Čirka, M. Bakošová, A. Kalmárová, J. Števek, K. Macušková, J. Holaza, J. Oravec, M. Kalúz, M. Jelemenský, J. Bendžala, S. Vagač, M. Fikar, B. Takács.

Missing: S. Blažek, J. Drgoňa, J. Mikleš, R. Paulen

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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 fifty-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 2014.

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 postgraduate 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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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 (Winter)		
Chemical Engineering Calculation on PC I	0/0/0/1	Kalúz, Števek
Computer Based Data Processing	0/0/0/2	Holaza, Jelemenský, Takács
2nd semester (Summer)		
Informatics	1/0/0/3	Bendžala, Kmeťová, Takács
Informatisation and Information Systems	1/0/0/2	Čirka, Kalúz
Operating Systems	0/0/0/3	Valo
3rd semester (Winter)		
Chemical Engineering Calculation on PC III	0/0/0/1	Števek
Modelling	2/0/0/3	Mészáros, Vasičkaninová
4th semester (Summer)		
Laboratory Excercises of Process Control	0/0/0/2	Klaučo, Oravec, Sharma
Optimisation	2/0/0/3	Klaučo, Kvasnica
Process Control	2/0/0/0	Bakošová
5th semester (Winter)		
Design of Information and Control Systems	2/0/0/3	Kvasnica, Valo
6th semester (Summer)		
Integrated Control in Process Engineering	2/0/0/3	Bakošová, Oravec, Vasičkaninová

Laboratory Excercises of Process Control	0/0/0/2	Holaza, Kalúz, Oravec, Števek, Vasičkaninová, Závacká
Process Control	2/0/0/0	Bakošová

2nd semester (Summer)

Chemical Engineering Calculation on PC III	0/0/0/1	Števek

5.2 Master Study

1st semester (Winter)

Information Technologies I	1/1/0/0	Čirka
Modelling in Process Industries	2/0/2/0	Bakošová, Vasičkaninová
Process Control and Dynamics	2/0/1/0	Bakošová, Vasičkaninová
Programming Internet Applications	1/0/2/0	Čirka
Semestral Project I	0/0/3/0	Čirka
Technical Means of Automation	2/0/2/0	Bendžala
Theory of Automatic Control I	2/0/3/0	Fikar, Klaučo

2nd semester (Summer)

Algorithms and Programming	1/2/0/0	Valo
Identification	2/0/2/0	Čirka, Fikar
Industrial Control and Information Systems 1	1/0/3/0	Kvasnica, Valo
Technological Process Control	1/1/0/0	Vasičkaninová
Theory of Automatic Control II	2/0/3/0	Čirka, Fikar

3rd semester (Winter)

Industrial Control and Information Systems 2	2/0/2/0	Kvasnica, Sharma
Information Technologies II	1/1/0/0	Čirka
Process Optimisation	2/0/2/0	Klaučo, Kvasnica
Theory of Automatic Control III	2/0/3/0	Fikar, Oravec

4th semester (Summer)

Model Predictive Control	2/0/1/0	Klaučo, Kvasnica
Robust Control	2/0/1/0	Bakošová, Oravec

5.3 PhD Study

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

5.4 Course Contents

5.4.1 Lectures in Bachelor Study

Optimization (2h/week, 4th semester) Introduction to optimization and motivating examples. Classification of optimization problems. Convex functions. Extrema of 1-D smooth functions. Extrema of n-D smooth functions. Analytical methods for unconstrained optimization. Constrained optimization with equality constraints. The Lagrange method for equality constrained optimization. Economic interpretation of Lagrange multipliers. Inequality constrained optimization. Karush-Kuhn-Tucker conditions. Simplex method for linear programming. Quadratic programming. Applications

of linear and quadratic programming. Introduction to nonlinear optimization. Introduction to mixed-integer optimization.

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 variables. 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 optimization of production systems with motivating examples. Analytical methods for unconstrained optimization. Numerical methods for unconstrained optimization. Gradient-free unconstrained optimization methods. Equality constrained optimization. Feasible and infeasible-start Newton

methods. Inequality constrained optimization, Karush-Kuhn-Tucker conditions. Complexity of optimization methods. Linear and quadratic programming with applications. Active set methods. Separation and classification problems. Integer optimization, formulation of mixed-integer optimization problems. Logic and mixed constraints. Algorithms for integer optimization.

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) Introduction to optimization of production systems with motivating examples. Analytical methods for unconstrained optimization. Numerical methods for unconstrained optimization. Gradient-free unconstrained optimization methods. Equality constrained optimization. Feasible and infeasible-start Newton methods. Inequality constrained optimization, Karush-Kuhn-Tucker conditions. Complexity of optimization methods. Linear and quadratic programming with applications. Active set methods. Separation and classification problems. Integer optimization, formulation of mixed-integer optimization problems. Logic and mixed constraints. Algorithms for integer optimization.

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, 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, J. Števek) 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, M. Jelemenský) 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.

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

Model Predictive Control (M. Fikar, M. Kvasnica, M. Klaučo, J. Holaza, B. Takács, J. Drgoňa, D. Ingole, J. Števek) 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, J. Jelemenský, A. Sharma) 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, Ľ. Čirka, M. Fikar, 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.

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

Control Engineering Education (M. Fikar, Ľ. Čirka, M. Bakošová, J. Oravec, R. Valo, J. Bendžala) 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, 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.

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 behaviour 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 neighbourhood 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.

6.2.5 Robust Model Predictive Control of Processes in Chemical and Food Industry (J. Oravec)

Internal Grant of the Slovak University of Technology in Bratislava

Period: 2014

The project is aimed to continue at research in the area of robust model predictive control (MPC) of the systems with uncertainties. The research is focused especially to the processes of chemical and food technologies, such as chemical reactors, heat exchangers and others. From the control viewpoint the main demands are the stability of the control, the quality of control performance, the optimization of energy resources, and the total computational burden of robust MPC design. The designed robust MPC will be validated using simulation of control and laboratory plants.

Project aims:

- study the possibilities of conservativeness reduction
- design of the robust MPC of uncertain multiple-input and multiple-output systems with input constraints

- develop software package for modeling and robust MPC of the processes of chemical and food technologies

6.2.6 Improved Slotting in IC automation design (J. Števek)

Internal Grant of the Slovak University of Technology in Bratislava

Period: 2014

In this project we address slotting problem in integrated circuit automation design for top-layer metals.

An integrating circuit production technology consists of many manufacturing steps - optical exposure, resist development, chemical vapour deposition and chemical-mechanical polishing (CMP) - have different influences on local characteristics of the layout. To keep these effects uniform and predictable the layout must be made uniform to certain density parameters. It is possible to achieve this uniformity by insertion (filling) or partial deletion (slotting) of shapes in a layout.

We propose to design slotting algorithm by means of multi-parametric programming. We focus on optimization problem for convex shapes of metal layers. Constraints of the problem will reflect restrictions of the production technology and limitation of the implementation environment. The solution should exhibit simple implementation and guarantees results in a real-time.

Objectives: A challenge is to design a slotting algorithm that offers solutions in a real time while satisfying all technology restrictions. Moreover algorithm has to respect limits of an implementation scripting language.

- complexity reduction
- use of optimization approaches for simplifying multi-parametric solution that were developed within project VEGA 1/0095/11

6.3 Other Projects in Slovak Republic

6.3.1 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

6.3.2 Slovkord s.r.o in Senica

Period: 11/2014 – 01/2015

- Analysis of data measured in PET production
- Statistical analysis

6.4 International Scientific Projects

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

Period: 2014–2018

Financing: European Commission – Framework Program 7, MC ITN

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

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

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

6.4.2 APVV SK-FR-2013-0026

Complexity, Sensitivity and Robustness in Explicit Model Predictive Control

Period: 2014 – 2015

Partners:

- Slovak University of Technology in Bratislava (M. Kvasnica, J. Drgoňa, J. Holaza, B. Takács)
- Ecole Superieur d'Electricite (SUPELEC) (P. Rodriguez-Ayerbe, S. Olaru, C. Vlad, A. Nguyen, T.M. Nguyen)

The proposed project is dedicated to the topic of model predictive control with a specific emphasis in their explicit solutions. The main goal is to develop new techniques for designing such control law with low complexity in view of deployment for fast real-time applications. In this project the scientific objective is to address complexity reduction in the explicit control laws, to analyse sensitivity of the optimal solutions and their implications to the robustness/fragility, and to apply developed algorithms in applications (power converters, or other appropriate benchmarks).

7 Cooperations

7.1 Cooperations in Slovakia

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

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, M. Fikar, A. Mészáros, J. Mikleš)
- Slovak Society of Industrial Chemistry (M. Bakošová, Ľ. Čirka, M. Fikar, A. Mészáros, J. Mikleš, A. Vasičkaninová)

7.4 Membership in International Organizations and Societies

- International Federation of Automatic Control, Laxenburg, Austria (M. Fikar)

- European Federation of Biotechnology, Brussels, Belgium (A. Mészáros)
- New York Academy of Sciences, New York, USA (A. Mészáros)
- European Union Control Association (M. Kvasnica)
- European Membrane Society (R. Paulen)
- IEEE (M. Fikar, M. Kalúz, M. Kvasnica)

8 Theses and Dissertations

8.1 Bachelor Theses (BSc. degree)

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

Benkovský, M.	Raspberry Pi with BrickPi module for controlling lego-robots (Valo, R.)
Bohunčáková, M.	Modeling of predator – prey system (Horanská, Ľ.)
Bučková, M.	Model Predictive Control of a Flexible Conveyor Belt (Kvasnica, M.)
Ďurina, P.	Timetable and Interactive Faculty Plan – Database Design and Data Processing (Fikar, M.)
Halás, R.	Timetable and Interactive Faculty Plan - Graphical User Interface (Fikar, M.)
Janeček, F.	Hierarchical control of group of vehicles (Kvasnica, M.)
Jaroš, B.	Hydraulic plant uDAQ28/3H industrial control (Valo, R.)
Javorská, T.	Controlling Systems with Dead - Time (Vasičkaninová, A.)
Kamenický, A.	Thermal-Optical Plant uDAQ28-LT from the Perspective of Industrial Controlling (Valo, R.)
Kecskés, M.	Forensic Examnation of Papers (Šutý. Š.)
Krippel, M.	The Classification and Prediction of Properties of Chemical Substances Using Neural Networks (Boor, Š.)
Lacková, Z.	A laboratory electrical drive from the point of view of industrial proceedings

	(Valo, R.)
Malíšek, I.	Programing of NXT Robots (Valo, R.)
Míková, N.	Internet version of the toolbox PIDDESIGN (Čirka, Ľ.)
Némethová, T.	Robust control of liquid tanks system (Vasičkaninová, A.)
Rišpanová, L.	Simulation of the EPR parameters using ab-initio approaches (Lukáš Bučinský)
Stupavský, I.	Web portal of Slovak Society of Industrial Chemistry (Čirka, Ľ.)

8.2 Master Theses (MSc. degree)

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

Andoková, J.	Control of Compressor for Offgas Recompression (Kvasnica, M.)
Franc, M.	Model Predictive Control of a Flexible Conveyor Belt (Kvasnica, M.)
Lacho, L.	Process analysis for production of PES technical fibre (Valo, R.)
Ľubušký, K.	Model of steam network 3.5 MPa in SLOVNAFT, Plc. (Kvasnica, M.)
Štefánik, M.	Modelling and Controlling of the Laboratory Distillation Column (Fikar, M.)
Szabová, E.	Predictive Controll of System “Ball and Plate” (Kvasnica, M.)

8.3 PhD's Theses (PhD. degree)

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

Kalúz, M.	Multipurpose and Low-Cost Architectures for Automatic Control Remote Laboratories (Fikar, M.)
Oravec, J.	Robust Model Predictive Control of Processes in Chemical Technologies (Bakošová, M.)
Szűcs, A.	Algorithms for Process Modelling and Fast Model Predictive Control (Fikar, M.)

9 Publications

9.1 Chapters or Pages in Books

1. Bakošová, M. – Závacká, J. – Oravec, J.: *Contributions of Automation and Process Control to Innovation in Chemical Industries (in Slovak)*, In *Nové trendy a inovácie v chémii*, Editor(s): Drtilová, I., Slovenská chemická knižnica FChPT STU v Bratislave, Bratislava, pp. 95–107, 2014.

9.2 Articles in Journals

1. Bakošová, M. – Oravec, J.: PDLF-based Robust MPC of a Heat Exchanger Network. **Chemical Engineering Transactions**, no. 39, pp. 145–150, 2014.

2. Bakošová, M. – Oravec, J.: Robust Model Predictive Control for Heat Exchanger Network. **Applied Thermal Engineering**, no. 1, vol. 73, pp. 924–930, 2014.

3. Bakošová, M. – Oravec, J.: Robust MPC of an Unstable Chemical Reactor Using the Nominal System Optimization. **Acta Chimica Slovaca**, no. 2, vol. 7, pp. 87–93, 2014.

4. Holaza, J. – Takács, B. – Kvasnica, M. – Di Cairano, S.: Nearly optimal simple explicit MPC controllers with stability and feasibility guarantees. **Optimal Control Applications and Methods**, no. 6, vol. 35, 2014.

5. Paulen, R. – Benyahia, B. – Latifi, M. A. – Fikar, M.: Analysis of optimal operation of a fed-batch emulsion copolymerization reactor used for production of particles with core–shell morphology. **Computers & Chemical Engineering**, vol. 66, pp. 233–243, 2014.

6. Vasičkaninová, A. – Bakošová, M.: Control of a Heat Exchanger Using Neural Network Predictive Controller and Auxiliary Fuzzy Controller. **Chemical Engineering Transactions**, no. 39, pp. 331–336, 2014.

9.3 Articles in Conference Proceedings

1. Bakošová, M. – Oravec, J.: Robust Model Predictive Control of a Laboratory Two–Tank System. In *American Control Conference*, Portland,

Oregon, USA, pp. 5242–5247, 2014.

2. Čirka, Ľ. – Kalúz, M. – Oravec, J. – Míková, N.: Designing PID Controllers Using MATLAB-SIMULINK Via the Internet. Editor(s): Byron, P., In *22nd Annual Conference Proceedings of the Technical Computing Bratislava 2014*, vol. 22, 2014.

3. Fikar, M.: Modelling, Control, and Optimisation of Membrane Processes. Editor(s): Ivo Petráš, Igor Podlubný, Ján Kačur, Radim Farana, In *Proceedings of 15th International Carpathian Control Conference*, Velke Karlovice, Czech Republic, pp. 109–114, 2014.

4. Hernández, R. – Simora, L. – Paulen, R. – Wegerhoff, S. – Mazaeda, R. – de Prada, C. – Engell, S.: Optimal Integrated Operation of a Sugar Production Plant. Editor(s): Jirí Jaromír Klemeš, Petar Sabev Varbanov, Peng Yen Liew, In *24th European Symposium on Computer Aided Process Engineering*, Elsevier B.V, Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands, vol. 2014, pp. 637–642, 2014.

5. Holaza, J. – Takács, B. – Kvasnica, M.: Verification of Performance Bounds for A-Posteriori Quantized Explicit MPC Feedback Laws. In *Preprints of the 19th IFAC World Congress Cape Town (South Africa) August 24 – August 29, 2014*, pp. 1035–1040, 2014.

6. Holaza, J. – Takács, B. – Kvasnica, M.: Simple Explicit MPC Controllers Based on Approximation of the Feedback Law. In *ACROSS Workshop on Cooperative Systems (WoCS 2014)*, pp. 48–49, 2014.

7. Jelemenský, M. – Paulen, R. – Fikar, M. – Kovacs, Z.: Time-Optimal Control of Batch Multi-Component Diafiltration Processes. Editor(s): Jirí Jaromír Klemeš, Petar Sabev Varbanov, Peng Yen Liew, In *24th European Symposium on Computer Aided Process Engineering*, Elsevier B.V, Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands, vol. 2014, pp. 553–558, 2014.

8. Jelemenský, M. – Paulen, R. – Fikar, M. – Kovacs, Z.: Time-optimal Diafiltration in the Presence of Membrane Fouling. In *Preprints of the 19th IFAC World Congress Cape Town (South Africa) August 24 – August 29, 2014*, pp. 4897–4902, 2014.

9. Kalúz, M. – Čirka, Ľ. – Valo, R. – Fikar, M.: ArPi Lab: A Low-cost Remote Laboratory for Control Education. In *Preprints of the 19th IFAC World Congress Cape Town (South Africa) August 24 – August 29, 2014*, 2014.

10. Klaučo, M. – Blažek, S. – Kvasnica, M. – Fikar, M.: Mixed-Integer SOCP Formulation of the Path Planning Problem for Heterogeneous Multi-Vehicle Systems. In *European Control Conference 2014*, Strasbourg, France, pp. 1474–1479, 2014.

11. Klaučo, M. – Drgoňa, J. – Kvasnica, M. – Di Cairano, S.: Building Temperature Control by Simple MPC-like Feedback Laws Learned from Closed-Loop Data. In *Preprints of the 19th IFAC World Congress Cape Town (South Africa) August 24 – August 29, 2014*, pp. 581–586, 2014.

12. Klaučo, M. – Jelemenský, M. – Valo, R. – Fikar, M.: Identification and Control of a Laboratory Distillation Column. Editor(s): J. Cigánek, Š. Kozák, A. Kozáková, D. Rosinová, In *Medzinárodná konferencia Kybernetika a Informatika '14*, Nakladateľstvo STU v Bratislave, Oščadnica, vol. 27, 2014.

13. Klaučo, M. – Kvasnica, M.: Explicit MPC Approach to PMV-Based Thermal Comfort Control. In *53rd IEEE Conference on Decision and Control*, Los Angeles, California, USA, vol. 53, pp. 4856–4861, 2014.

14. Lucia, S. – Paulen, R.: Robust Nonlinear Model Predictive Control with Reduction of Uncertainty Via Robust Optimal Experiment Design. In *Preprints of the 19th IFAC World Congress Cape Town (South Africa) August 24 – August 29, 2014*, pp. 1904–1909, 2014.

15. Lucia, S. – Paulen, R. – Engell, S.: Multi-stage Nonlinear Model Predictive Control with Verified Robust Constraint Satisfaction. In *53rd IEEE Conference on Decision and Control*, Los Angeles, California, USA, vol. 53, pp. 2816–2821, 2014.

16. Matejičková, K. – Bakošová, M. – Ševčík, P.: Robust PI Controller Design. Editor(s): Markoš, J., In *Proceedings of the 41st International Conference of Slovak Society of Chemical Engineering*, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 408–417, 2014.

17. Paulen, R. – Villanueva, M. – Chachuat, B.: Higher-Order Inclusion Techniques for Guaranteed Parameter Estimation of Nonlinear Dynamic Systems. In *Proceedings of the 2014 AIChE Annual Meeting*, 2014.

18. Stathopoulos, G. – Szűcs, A. – Pu, Y. – Jones, C.: Splitting methods in control. In *European Control Conference 2014*, Strasbourg, France, 2014.

19. Števek, J. – Fikar, M.: A heuristic approach for complexity reduction in explicit MPC – border based technique. Editor(s): J. Cigánek, Š. Kozák, A. Kozáková, D. Rosinová, In *Medzinárodná konferencia Kybernetika a Informatika '14*, Nakladateľstvo STU v Bratislave, Oščadnica, vol. 27, 2014.

20. Števek, J. – Kvasnica, M. – Fikar, M. – Vrbický, A.: An Application of Multi-parametric Programming in Integrated Circuit Automation (Slotting Problem). In *Preprints of the 19th IFAC World Congress Cape Town (South Africa) August 24 – August 29, 2014*, pp. 10275–10280, 2014.

21. Vasičkaninová, A. – Bakošová, M.: Control of a Heat Exchanger Using Takagi-Sugeno Fuzzy Model. Editor(s): Ivo Petráš, Igor Podlubný, Ján Kačur, Radim Farana, In *Proceedings of 15th International Carpathian Control Conference*, Velke Karlovice, Czech Republic, pp. 646–651, 2014.

22. Vasičkaninová, A. – Bakošová, M. – Kmeťová, J.: Fuzzy Control of a Heat Exchanger Using Fuzzy C-Means Clustering Algorithm. Editor(s): Markoš, J., In *Proceedings of the 41st International Conference of Slovak Society of Chemical Engineering*, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 917–926, 2014.

23. Závacká, J. – Vasičkaninová, A. – Bakošová, M.: Control of a Continuous Stirred Tank Reactor Using Advanced Approaches. In *21th International Congress of Chemical and Process Engineering*, Orgit s.r.o., Praha, Czech Republic, 2014.