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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M. Paulovič, J. Závacká, M. Kvasnica, L. Blahová, Ľ. Čirka,
M. Karšaiová, M. Herceg, M. Bakošová, M. Fikar, S. Vagač
(Missing: J. Dvoran, A. Kalmárová, J. Mikleš, M. Podmajerský)

CONTENTS

I 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 optimisation 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 modelling 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.

II 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 2009.

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, PhD, DSc in 1962 – 1986. Prof. Ján Mikleš, PhD, DSc headed the department in 1986 – 1994 and in 1998 – 2003. The head in 1995 – 1997 was Assoc. Prof. Alojz Mészáros, PhD and Prof. Dr. Ing. Miroslav Fikar 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 Information Engineering, Automation and Management in Chemical and Food Industry, master study program Information Engineering and Automation in Chemical and Food Industry and PhD study program Process Control.

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Neural Networks, Modelling and
Control of Biochemical Processes

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IV TEACHING AND RESEARCH LABORATORIES

IV.1 Teaching Laboratories

Laboratory of Process Control
Laboratory of Control Systems
Computer Laboratory (PC - Windows, Linux)
Computer Laboratory (Solaris)

IV.2 Research Laboratories

Laboratory of Control Theory
Laboratory of Modelling and Simulation
Laboratory of Identification
Laboratory of Optimisation
Laboratory of Neural Networks
Laboratory of Fuzzy Control and Expert Systems
Laboratory of Robust Control
Laboratory of Chemical Reactor Analysis and Control
Laboratory of Biochemical Process Analysis and Control
Laboratory of Distillation Column Analysis and Control
Laboratory of Computer Aided Design (Siemens-SIMATIC S-7 300, FOXBORO, dSPACE, MATLAB/Simulink)

V. EDUCATIONAL ACTIVITIES

V.1 Bachelor Study

2nd semester (spring)

Computer Based Data Processing	0/0/2	Karšaiová, Vaneková
Optimisation	3/3/0	Dvoran, Blahová

4th semester (spring)

Modelling	2/3/0	Bakošová, Vasičkaninová, Závacká
Operating Systems	1/2/0	Fikar, Podmajerský

5th semester (autumn)

Process Control	2/0/0	Bakošová
Laboratory Exercises of Process Control	0/0/2	Karšaiová, Vaneková
Design of Information and Control Systems	2/3/0	Kvasnica, Herceg, Závacká

6th semester (spring)

Bachelor Projects	0/0/9	Bakošová, Čirka, Fikar, Kvasnica, Karšaiová, Vasičkaninová, Závacká
Process Control	2/0/0	Bakošová
Laboratory Exercises of Process Control	0/0/2	Karšaiová, Paulen, Vasičkaninová, Vöröš, Závacká
Computer Based Data Processing	0/0/2	Karšaiová
Integrated Control in Process Engineering	2/0/3	Bakošová, Karšaiová, Vasičkaninová
Information Engineering and Systems	1/2/0	Čirka

Laboratory Exercises of Information Engineering and Systems	0/0/2	Čirka

V.2 Master Study

1st semester (autumn)

Semestral Project I	0/0/3	Bakošová, Čirka, Fikar, Kvasnica, Vasičkaninová
Programming of Network Application	1/0/2	Čirka, Paulovič
Technical Means of Automation	2/0/2	Juhás
Modelling in Process Industries	2/0/2	Bakošová, Karšaiová
Automatic Control Theory I	3/0/2	Mikleš, Vasičkaninová
Process Dynamics and Control	2/0/1	Bakošová, Karšaiová, Vasičkaninová
Information Technologies I	1/1/0	Čirka, Paulovič, Vaneková

2nd semester (spring)

Informatization and Industrial Information Systems I	2/0/1	Kvasnica, Paulen, Vaneková
Identification	2/0/2	Čirka, Fikar
Automatic Control Theory II	3/0/2	Herceg, Mészáros
Semestral Project II	0/0/3	Bakošová, Čirka
Information Technologies II	1/1/0	Čirka
Technological Process Control	1/1/0	Dvoran

3rd semester (autumn)

Automatic Control Theory III	3/0/2	Fikar, Herceg, Závacká

Informatization and Industrial Information Systems II	2/0/2	Kvasnica, Herceg, Paulen
Optimization of Processing and Production	2/0/2	Dvoran, Blahová
Diploma Project	0/0/4	Bakošová, Blahová, Čirka, Fikar, Karšaiová, Kvasnica, Paulen, Vaneková, Závacká

4th semester (spring)

Diploma Thesis	0/0/17	Čirka, Fikar, Mészáros, Vasičkaninová

V.3 PhD Study

1st semester (autumn)

Control Theory (Selected topics)	4/0/0	Mészáros

2nd semester (spring)

Control Theory II (Selected topics)	2/0/0	Mikleš

3rd semester (autumn)

Modelling and Control of Chemical Processes	2/0/0	Bakošová
Identification of Dynamic Systems	2/0/0	Fikar
Intelligent Control Systems	2/0/0	Dvoran

V.4 Course contents

V.4.1 Lectures in Bachelor study

Optimisation (3h/week, 2nd semester)

Static optimisation, classification of problems, goal functions, boundaries. Extremum without boundaries – analytical methods. Single-dimensional case, multi-dimensional case, Hess matrix. Conditions for extremum. Extremum with boundaries – linear boundaries, direct method, method of Lagrange multipliers. Extremum 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, Broyde method, DFP method, PARTAN method. Convergence of gradient methods.

Modelling (2h/week, 4th semester)

Fundamentals of chemical process modelling 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. Nonliner and linearized mathematical models of continuous stirred tank reactors. Dynamic and static behaviour of processes.

Operating Systems (1h/week, 4th 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, 5th and 6th semester)

Introduction to process control. Modelling of special types of processes of chemical technology. Static and dynamic behaviour of controlled systems. Closed loop for control of technological processes. Controllers. Dynamic behaviour 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 feedforward control. More complex control structures: cascade control, feedforward-feedback control, control loop with auxiliary control input, time-delay compensator – Smith predictor, flow-ratio control, special cases of multivariable control. Process control: control of storage tanks, control of mixing units, control of heat exchangers, control of distillation columns, control of chemical reactors.

Information Engineering and Systems (1h/week, 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. Visualisation 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 pre Windows XP/2000/NT). Creating HTML application and dynamic web pages bounded to control system databases, SCADA/HMI systems etc.

V.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 behaviour. Discrete controllers, their dynamic behaviour 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.

Modelling in Process Industries (2h/week, 1st semester)

Introduction to modelling in process engineering, modelling importance, static and dynamic mathematical models of liquid storages, shell and tube heat exchangers, packed and deck distillation columns, adsorption columns, extraction columns, continuous and batch chemical and biochemical reactors, tube chemical reactors with or without catalyst.

Automatic Control Theory I (3h/week, 1st semester)

Continuous-time systems, discrete systems. Pole-placement method. State-space approach. Deterministic state estimate. Dynamic output feedback. Connections between state and input-output approach to control design. Pseudo-state. Asymptotic observer. Control law based on an observer for deterministic problem. Fractional approach, set of all stabilizing controllers. BIBO stability. Parameterisation of stabilizing controllers. Bezaut equation. Dynamic optimisation. Principle of minimum. Fundamental theorem of the variation calculus. Necessary conditions for the optimal control. LQC problem. Kalman linear (L), quadratic (Q) controller. Euler-Lagrange equations. Optimal control. Matrix Riccati equation. Output control. LQ controller with integral properties. LQ control. Connections between the state-space and input-output approaches. Spectral factorisation. LQ control and deterministic state estimation. Polynomial solution of the problem. PI controllers and LQ controller design. Optimal LQ tracking of SISO systems, input-output approach. State and parameter identification. LQ state controller, LQG input-output controller. H_2 feedback control. Solution by using of two generalized algebraic Riccati equations. Connection between LQG and H_2 control.

Process Dynamics and Control (2h/week, 1st semester)

Introduction to control of technological processes. Principles of control of technological processes: feedback and feedforward control. Simple feedback control loop. Methods for PID controller tuning. Complex control loops: time-delay compensation (Smith predictor), cascade control, feedforward 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.

Informatization and Industrial Information Systems I (2h/week, 2nd semester)

Basic principles and stages of industrial information system design. System reliability and diagnostics. Projecting and control desig of selected technologies using an appropriate software. PLC systems and Profibus. WinCC visualisation 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 multivariable and continuous-time systems. Aspects of the least square method and identification of static models, passive and active experiment.

Automatic Control Theory II (3h/week, 2nd semester)

Description of inputs, outputs, and state of discrete systems. Internal properties of discrete systems. A synthesis of discrete regulators. Definition and principles of adaptive control, its direct and non-direct methods. System robustness and methods of robust control. MIMO models, Diophant equations for MIMO systems. PA, LQ, and LQG control. Factorization and parametrization.

Information Technologies II (1h/week, 2nd 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 (3h/week, 3rd semester)

MIMO systems definition. Quality criteria for MIMO systems control. Robustness and robust stability. Classification of uncertainities. Feedback MIMO systems. MIMO LQ and LQG control. H2 and Hinf MIMO control with and without modelling. Model reduction.

Informatization and Industrial Information Systems II (2h/week, 3rd semester)

An analysis of possibilities to control a technological process using industrial information systems. Communication and technological process data collection. Programming tools and visualization methods.

Optimization of Processing and Production (2h/week, 3rd semester)

Application of optimization methods for solving of optimization problems of tehcnological processing and production. Optimization methods of one-variable and multiple variables functions, with and without restrictions. Non-gradient optimization methods – simplex methods, gradient methods and evolution algorithms.

V.4.3 Laboratory exercises in Bachelor study

Computer Based Data Processing (2h/week, 2nd 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.

Optimisation (3h/week, 2nd semester)

Extremum without boundaries – analytical methods. Single-dimensional case, multi-dimensional case. Extremum with boundaries – linear boundaries, direct method, method of Lagrange multipliers. Extremum 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, 5th and 6th semester)

MATLAB/Simulink as a simulation tool for LEACF. Laplace transform as a mathematical tool for LEACF. Input-output description of dynamic systems, transfer functions, poles and zeros. Step responses and impulse responses of dynamic systems. Mathematical models and dynamic behaviour 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.

VI. 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.

VI.1 Main Research Areas

Modelling and Simulation (M. Bakošová, M. Karšaiová, A. Mészáros, J. Mikleš)

Modelling and simulation play an important role in the investigation of static and dynamic properties of chemical processes, units and systems. Most chemical systems are strongly non-linear and their simulation is necessary for the control design as well as for the investigation of the overall control systems. The main aim of the research is to develop program packages for modelling and simulation of various kinds of models. During the last year a package for PC in Simulink and C-language 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:

- nonparameteric 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 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 behaviour. To apply a successful control design to practical problems is a substantial effort. The processes are known to be modelled and controlled with serious difficulties caused by their non-linear behaviour, high order dynamics, and tendency to instability. Many of industrial processes must be considered as multivariable systems. In a great deal of available control design techniques it is often necessary to carry out the steps of modelling, 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 - characterised by repeating parameter estimation and control design
- model reference adaptive control based on the Lyapunov method
- decentralised 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 optimising 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 parameterisation of all stabilising 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 behaviour. 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)

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 behaviour 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.

Robust Control (M. Bakošová)

Chemical processes are usually very complicated systems from the control point of view because of their strong nonlinearity, varying operating points, not exactly known dynamics, varying or not exactly known parameters. All these problems can be included into mathematical models of chemical processes either in the form of parametric or dynamic uncertainty and robust control is a suitable tool for such processes. The research in this field is focused especially on robust static output feedback stabilization of chemical processes.

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.

VI.2 Research Projects in Slovak Republic

1. VEGA 1/4055/07: Advanced Approaches to Control of Chemical and Biochemical Processes with Uncertainties (M. Bakošová)

The project deals with development of advanced approaches to control of systems with uncertainties and focuses on processes typical for chemical and food technologies, as e.g. chemical reactors, biochemical reactors, distillation columns, and others. Development of methods of robust analysis, robust stabilization and robust control of systems with uncertainties constitutes the core of the project. Processes with recycle can be also included to the systems with uncertainties. Designed algorithms, controllers, and control structures will be tested by simulations and in laboratory conditions. Obtained results will be transferred to the industrial praxis.

Period: 2007-2009

2. VEGA 1/0071/09: Advanced Methods of Optimal Control of Chemical and Biochemical Processes (M. Fikar)

The project deals with research and development of modern optimal control and optimisation methods and focuses into processes typical in chemical and food industries: chemical reactors, distillation columns, waste-water treatment plants, and others. It involves hybrid systems, dynamic and global optimisation methods, predictive control as well as supervisory control with particular stress on computational efficiency and realisability in industry. Developed algorithms, controllers, and control structures will be tested by simulations and in laboratory conditions.

Period: 2009-2011

3. LPP-0092-07: Model Predictive Control of Hybrid Systems (M. Kvasnica)

The aim of this project is to extend the knowledge about parametric solutions to MPC problems for the class of hybrid systems. This involves, among other tasks, design of new algorithms for synthesis of robust control laws for the class of hybrid systems and new methods for

state estimation for such systems. Modeling of compositional hybrid systems will be investigated as well. The goal is to create a software package which provides these algorithms to a broad range of users.

Period: 2008-2011

4. APVV-0029-07: Algorithms for Optimal Control of Heat and Mass Transfer Processes with Hybrid Dynamics (M. Fikar)

The project is focused on research in the areas of methods, algorithms and means for modelling and identification of technological units in process industries, as well as on design and implementation of algorithms for synthesis, analysis and final implementation of control systems to aforementioned processes. Partial methods and algorithms will be designed with high focus on effectiveness of their respective implementation, which will decrease the purchasing and operating costs of control systems for processes with heat and mass transfer that can be described by hybrid models.

Period: 2008-2010

VI.3 International Scientific Programs

1. Project of French – Slovak Scientific Cooperation Štefánik

Dynamic and Global Optimisation of Processes

Partners:
- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (M. Fikar, R. Paulen)

- 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 mathematic models, typically with non-linear and differential equations. The optimisation 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 optimise (minimise, maximise) 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 is known as dynamic optimisation (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, determination of optimal control trajectory during set-point change, security analysis of processes, model based predictive control based on continuous model, etc.

Period: 2008-2009

2. Project of Swiss – Slovak Scientific Cooperation

Software for Modeling and Simulation of Hybrid Systems

Partners:
- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (M. Kvasnica, M. Herceg)

- ETH Zurich, Automatic Control Laboratory (M. Morari)
- ABB Switzerland

This project is aimed at extending the HYSDEL language such that modeling of complex hybrid systems can be performed in an easy and efficient way. The language will be extended to allow to create compositional hybrid systems (i.e. systems which consist of several sub-modules). Moreover, the user will have the possibility to create such composition graphically by joining selected blocks in the MATLAB/SIMULINK environment.

Period: 2007 – 2009

3. Project of Slovak – Czech Scientific Cooperation

Algorithms for Control of Processes with Mass and Heat Transfer

Partners:
- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (project leader: M. Bakošová)

- T. Bata University in Zlín, Fakulty of Applied Informatics (project leader: R. Prokop)

Principal investigator from IIEAM: M. Bakošová
Scientific co-workers from IIEAM: M. Fikar, A. Mészáros, M. Kvasnica, A. Vasičkaninová, K. Vaneková, J. Závacká

The project is focused on development of advanced control algorithms for control of typical processes in chemical and food technologies, as e.g. heat exchangers, distillation columns, chemical reactors, etc. Control algorithm design is based on chosen robust control methods and optimal control methods. The core of the project represents development of robust control methods for systems with parametric uncertainty and of optimisation methods with evolution algorithms. Designed control algorithms, controllers and control structures will be tested via simulations and on real laboratory processes.

Period: 2008-2009

4. Project of Slovak - Hungarian Scientific Cooperation

Modelling, Optimisation, and Control of Heat and Mass Transfer Processes

Partners:
- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (M. Fikar, M. Bakošová, A. Mészáros, M. Herceg)

- Budapest University of Technology and Economics, Faculty of Chemical Engineering (P. Mizsey, Z. Szitkai, M. Gábor, M. Horváth)

The collaboration is planned to be conducted in two phases:

I. Continuation and completion of research activities on the following topics:

- Study of separation processes for non-ideal mixtures
- Analysis, simulation and control of hybrid separation processes
- Modelling and dynamic analysis of a multicolumn distillation process
- Hybrid process modelling using artificial neural networks (ANN)
- Development and implementation of dynamic optimisation packages

II. Modification and extension of the above topics as follows:

- Adaptive process control design using ANN
- Robust intelligent control design
- Static and dynamic optimisation of separation processes
- Testing of the proposed new algorithms for non-linear chemical processes through simulation experiments
- Implementation of computer control for laboratory fermenter
- Publication of the results obtained

Period: 2007-2009

5. Project of Slovak – Hungarian Scientific Cooperation

Advanced Optimization and Control Methods for Processes with Energy Savings

Partners:
- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Inform. Eng. and Process Control (A. Mészáros, M. Bakošová, M. Fikar)

- University of Pannonia, Veszprem (F. Friedler, J. Klemes, P. Varbanov)

The collaboration is conducted in the field of development of advanced methods for optimization and control of processes leading to energy savings. The research interests are focused in the field of neural-network based control, robust control of processes with various types of uncertainty and dynamic optimization.

Period: 2009-2010

VII. COOPERATION

VII.1 Cooperation in Slovakia

- Institute of Control and Industrial Informatics, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Bratislava

- Institute of Automation, Measurement, and Applied Informatics, Faculty of Mechanical Engineering, 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

- Institute of Control and Informatization of Production Processes, BERG Faculty, Technical University of Košice, Košice

- Slovnaft, Inc., Bratislava

- NCHZ, Inc., Nováky

- Fuzzy, Ltd., Diakovce

- ProCS, Ltd., Šaľa

VII.2 International Cooperation

- 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, Predictive Control)

- Trnka Laboratory for Automatic Control, Faculty of Electrical Engineering, Czech Technical University, Prague, Czech Republic
  (Adaptive control, Model Predictive Control)

- LSGC-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 Bochum, Bochum, Germany
  (Closed-loop identification, Model Predictive control)

- University of Dortmund, Dortmund, Germany
  (Model Predictive Control)

- Technical University of Budapest, Budapest, Hungary
  (Modelling of chemical processes)

- University of Veszprem, Hungary
  (Environmental engineering, Bioengineering projects)

VII.3 Membership in Domestic Organizations and Societies

- Slovak Society for Cybernetics and Informatics (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)

VII.4 Membership in International Organizations and Societies

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

- Czech Society of Chemical Engineering (M. Bakošová)

VIII. THESES AND DISSERTATIONS

VIII.1 Graduate Theses (Bc Degree)

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

Babulíková, M. Control Systems
(Karšaiová, M.)

Bodnár, P. Dynamic Creation of Images in the SVG Format
(Čirka, Ľ.)

Chroustová, K. Control of LEGO Robots
(Kvasnica, M.)

Dubovský, D. Generation of Plant Responses Using AJAX
(Čirka, Ľ.)

Grancová, J. Control of LEGO Robots
(Kvasnica, M.)

Hodasová, M. SAP - Barcode Implementing in the Control Fiscal Assets
(Vasičkaninová, A.)

Hulata, T. Fuzzy Controllers Design in Matlab
(Vasičkaninová, A.)

Kunovská, J. Comparison of Projects for Generation of Timetables
(Fikar, M.)

Kureková, G. Digitisation of Historical Documents on Lignocellulose Information Sources (Fikar, M.)

Kušev, S. Creation of Web Pages
(Čirka, Ľ.)

Mikušová, K. Modelling and Control of the Laboratory Process PCT40
(Bakošová, M.)

Mitterpach, B. Convex Optimization and Model Predictive Control
(Kvasnica, M.)

Náglová, K.	Measurement and Level Control on Laboratory Model PCT40 (Fikar, M.)
Osif, Ľ.	Web Application for Data Processing and Analysis (Čirka, Ľ.)
Sónak, M.	Control of Laboratory Liquid Tank (Závacká, J.)
Tomeček, F.	Process Identification Based on ANFIS (Vasičkaninová, A.)
Wenchich, J.	Process Identification Based on ANFIS (Vasičkaninová, A.)

VIII.2 Graduate Theses (MS Degree)

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

Gocian, J.	Control of Systems Using Adaptive Neural Controllers (Fikar, M.)
Lanák, R.	Vacation Module for Web-based System of IIEAM (Čirka, Ľ.)
Rubický, T.	IMC Fuzzy Control (Vasičkaninová, A.)
Zika, R.	Development of a New Information System in Projecting for Intech Control(Meszáros, A.)
Zubček, M.	Management System of Prosthetic Production (Čirka, Ľ.)

VIII.3 Graduate Theses (PhD Degree)

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

Herceg, M. Real-Time Explicit Model Predictive Control of Processes
(Fikar, M.)

Puna, D. Robust Control of Chemical Reactors
(Bakošová, M.)

IX. PUBLICATIONS

IX.1 Books

1 Kvasnica, M.: Real-Time Model Predictive Control via Multi-Parametric Programming: Theory and Tools, VDM Verlag, Saarbruecken, 2009.

IX.2 Chapter or pages in book

1 Bemporad, A., Di Cairano, S., Ferrari-Trecate, G., Kvasnica, M., Morari, M., Paoletti, S.: Tools for Modeling, Simulation, Control, and Verification of Piecewise Affine Systems, In Handbook of Hybrid Systems Control: Theory, Tools, Applications, Editor(s): J. Lunze, F. Lamnabhi-Lagarrigue, Cambridge University Press, pp. 297–324, 2009.

2 Herceg, M., Kvasnica, M., Fikar, M.: Parametric Approach to Nonlinear Model Predictive Control, in Nonlinear Model Predictive Control, Editor(s): Magni, L. and Raimondo, D. M. and Allgoewer, F., Springer Berlin / Heidelberg, pp. 381–389, 2009.

IX.3 Article in journal

1 Bakošová, M., Puna, D., Dostál, P., Závacká, J.: Robust Stabilization of a Chemical Reactor. Chemical Papers, no. 5, vol. 63, pp. 527–536, 2009.

2 Blahová, L., Dvoran, J.: Neuro-fuzzy Control of Chemical Technological Processes (in Slovak). Strojárstvo EXTRA, no. 5/09, vol. 8, pp. 3/1–3/3, 2009.

3 Blahová, L., Dvoran, J.: Neuro-fuzzy Control of a Chemical Reactor (in Slovak). Transfer inovácií, no. 14, pp. 55–60, 2009.

4 Čižniar, M., Podmajerský, M., Hirmajer, T., Fikar, M., Latifi, M. A.: Global Optimization for Parameter Estimation of Differential-algebraic Systems. Chemical Papers, no. 3, vol. 63, pp. 274–283, 2009.

5 Fikar, M., Čirka, Ľ.: E-learning Course on System Identification (in Slovak). Transfer inovácií, no. 14, pp. 9–12, 2009.

6 Herceg, M., Kvasnica, M., Fikar, M.: Minimum-time Predictive Control of a Servo Engine with Deadzone. Control Engineering Practice, no. 11, vol. 17, pp. 1349–1357, 2009.

7 Herceg, M., Kvasnica, M., Fikar, M., Čirka, Ľ.: Real-time Control of a Thermo-Optical Device Using Polynomial Approximation of MPC Scheme. AT&P Journal Plus, no. 2, pp. 36–42, 2009.

8 Hulkó, G., Belavý, C., Mészáros, A., Buček, P., Ondrejkovič, K., Zajíček, P.: Engineering Methods and Software Support for Modelling and Design of Discrete-time Control of Distributed Parameter Systems. European Journal of Control, no. 3-4, vol. 15, pp. 407–417, 2009.

9 Mészáros, A., Čirka, Ľ., Šperka, Ľ.: Intelligent Control of a pH Process. Chemical Papers, no. 2, vol. 63, pp. 180–187, 2009.

10 Mészáros, A., Čirka, Ľ.: Control Analysis for Processes with Internal Recycle. Chemical Engineering Transactions, no. 18, pp. 731–736, 2009.

11 Paulen, R., Fikar, M., Čižniar, M., Latifi, M. A.: Global Optimization for Parameter Estimation of Dynamic Systems. AT&P Journal Plus, no. 2, pp. 71–78, 2009.

12 Podmajerský, M., Fikar, M.: On-Line Neighbouring-Extremal Controller Design for Setpoint-Transition in Presence of Uncertainty. AT&P Journal Plus, no. 2, pp. 77–83, 2009.

13 Uher, D., Čirka, Ľ., Kamenár, J., Híveš, J.: A New Type of Alumnium Smelting Baths-Electrical Conductivity. Acta Chimica Slovaca, no. 1, vol. 2, pp. 25–30, 2009.

14 Vaneková, K., Bakošová, M., Matušů, R., Závacká, J.: Robust Control of a Laboratory Process. AT&P Journal Plus, no. 2, pp. 98–103, 2009.

15 Vasičkaninová, A., Bakošová, M.: Neural Network Predictive Control of a Chemical Reactor. Acta Chimica Slovaca, no. 2, vol. 2, pp. 21–36, 2009.

16 Vöröš, J., Mikleš, J., Čirka, Ľ.: A Comparision of Different EKF Approaches for Parameters Estimation. AT&P Journal Plus, no. 2, pp. 31–35, 2009.

17 Závacká, J., Bakošová, M., Vaneková, K.: Control of a Laboratory Chemical Reactor Using Robust PI Controller (in Slovak). Automatizace, no. 6, vol. 52, pp. 362–365, 2009.

18 Závacká, J., Bakošová, M., Vaneková, K.: Control of Laboratory Chemical Reactor Using Robust PI Controller. AT&P Journal Plus, no. 2, pp. 84–88, 2009.

19 Závacká, J., Bakošová, M., Matušů, R., Vaneková, K.: Robust Control of a Mixing Unit. Transfer inovácií, no. 14, pp. 65–70, 2009.

IX.4 Article in conference proceedings

1 Bakošová, M., Puna, D., Vasičkaninová, A., Karšaiová, M.: Robust PI and PID Stabilization of a Chemical Reactor. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control ’09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 443–452, 2009.

2 Bakošová, M., Oravec, J.: Software for PID Controller Tuning. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control ’09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 524–527, 2009.

3 Bakošová, M., Puna, D., Závacká, J., Vaneková, K.: Robust Static Output Feedback Control of a Mixing Unit. In Proceedings of the European Control Conference 2009, EUCA, Budapest, pp. 4139–4144, 2009.

4 Bakošová, M., Vasičkaninová, A.: Simulation of Robust Stabilization of a Chemical Reactor. Editor(s): Javier Otamendi, Andrzej Bargiela, José Luis Montes , Luis Miguel Doncel Pedrera, In Proceedings 23rd European Conference on Modelling and Simulation ECMS 2009, Digitaldruck Pirrot GmbH 66125 Sbr.-Dudweiler, Germany, Rey Juan Carlos University, Madrid, Spain, vol. 23, pp. 570–576, 2009.

5 Bakošová, M., Oravec, J., Čirka, Ľ.: Software for PID Controller Tuning. In Technical Computing Prague 2009, Humusoft, s.r.o., pp. 15-1–15-8, 2009.

6 Bakošová, M.: E-learning in the Course Integrated Control in the Process Industry. Editor(s): Huba, M., In Proceedings of 10th International Conference Virtual University, E-academia Slovaca, Bratislava, pp. 70.pdf, 2009.

7 Bisták, P., Čirka, Ľ.: Reservation of Remote Laboratory using Moodle LMS. Editor(s): Huba, M., In Proceedings of 10th International Conference Virtual University, E-academia Slovaca, Bratislava, 2009.

8 Blahová, L., Dvoran, J.: Neuro-fuzzy Control of Chemical Technological Processes (in Slovak). In Automatizácia a riadenie v teórii a praxi, Technická univerzita v Košiciach, Stará Lesná, SR, pp. 04Blahova_Dvoran.pdf, 2009.

9 Blahová, L., Dvoran, J.: Neural-Fuzzy Control of Chemical Technological Processes. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control ’09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 268–272, 2009.

10 Blahová, L., Dvoran, J.: Intelligent Control of Chemical-Technological Processes. Editor(s): J. Markoš, In 36th International Conference of Slovak Society of Chemical Engineering, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 146-1–146-8, 2009.

11 Blahová, L., Dvoran, J.: Intelligent Control of Chemical Reactor with Disturbances (in Slovak). Editor(s): prof. Ing. Bohumil Šulc, CSc., In Sborník přednášek z technické konference ARaP 2009, DIMART s.r.o., Praha, vol. 5, pp. 87–92, 2009.

12 Čirka, Ľ., Fikar, M.: E-learning on System Identification. Editor(s): Huba, M., In Proceedings of 10th International Conference Virtual University, E-

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14 Herceg, M., Kvasnica, M., Fikar, M., Čirka, Ľ.: Real-Time Control of a Thermo-Optical Device Using Polynomial Approximation of MPC Scheme. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control '09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 332–340, 2009.

15 Kovacs, Z., Fikar, M., Czermak, P.: Mathematical Modeling of Diafiltration. In Conference of Chemical Engineering, Pannonia University, Veszprem, pp. 135–135, 2009.

16 Kvasnica, M., Herceg, M., Čirka, Ľ., Fikar, M.: Time Optimal Control of Fuzzy Systems: a Parametric Programming Approach. In Proceedings of the 28th IASTED Conference on Modelling, Identification and Control, pp. 640-805.pdf, 2009.

17 Kvasnica, M., Herceg, M., Čirka, Ľ., Fikar, M.: Time-Optimal Control of Takagi-Sugeno Fuzzy Systems. In Proceedings of the 10th European Control Conference, Budapest, Hungary, pp. 916–921, 2009.

18 Kvasnica, M., Herceg, M., Čirka, Ľ., Fikar, M.: Robust Adaptive Minimum-Time Control of Piecewise Affine Systems. In Proceedings of the 48th IEEE Conference on Decision and Control, pp. 2454–2459, 2009.

19 Matušů, R., Vaneková, K., Prokop, R., Bakošová, M.: Robust Proportional-Integral Control of a Laboratory Model Using Programmable Logic Controller SIMATIC S7-300. In Preprints of the 6th IFAC Symposium on Robust Control Design, 2009.

20 Paulen, R., Fikar, M., Čižniar, M., Latifi, M. A.: Global Optimization for Parameter Estimation of Dynamic Systems. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control '09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 86–92, 2009.

21 Podmajerský, M., Fikar, M.: On-Line Neighbouring-Extremal Controller Design for Setpoint-Transition in Presence of Uncertainty. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control '09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 107–113, 2009.

22 Polóni, T., Takács, G., Kvasnica, M., Rohaľ-Ilkiv, B.: System Identification and Explicit Predictive Control of Cantilever Lateral Vibrations. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control ’09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 309–313, 2009.

23 Rauová, I., Kvasnica, M., Čirka, Ľ., Fikar, M.: Real-Time Model Predictive Control of a Laboratory Liquid Tanks System. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control ’09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 304–308, 2009.

24 Vaneková, K., Bakošová, M., Matušů, R., Závacká, J.: Robust Control of a Laboratory Process. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control ’09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 613–618, 2009.

25 Vaneková, K., Bakošová, M., Závacká, J.: Robust Control of a Laboratory Time Delay Process. Editor(s): J. Markoš, In 36th International Conference of Slovak Society of Chemical Engineering, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 117–1–117–9, 2009.

26 Vasičkaninová, A., Bakošová, M.: Neural Network Predictive Control of a Chemical Reactor. Editor(s): Fikar, M., Kvasnica, M., In Proceedings of the 17th International Conference on Process Control ’09, Slovak University of Technology in Bratislava, Štrbské Pleso, Slovakia, pp. 426–431, 2009.

27 Vasičkaninová, A., Bakošová, M.: Fuzzy Logic Control of a Tube Heat Exchanger. Editor(s): J. Markoš, In 36th International Conference of Slovak Society of Chemical Engineering, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 055-1–055-10, 2009.

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IX.5 Phd thesis

1 Herceg, M.: Real-Time Explicit Model Predictive Control of Processes. ÚIAM FCHPT STU v Bratislave, Radlinského 9, 812 37 Bratislava, 2009.

2 Puna, D.: Robust Control of Chemical Reactors (in Slovak). ÚIAM FCHPT STU v Bratislave, Radlinského 9, 812 37 Bratislava, 2009.