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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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 study branch Chemical Engineering and Process Control on the specialization Process Control, 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 our country. 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.

Assoc. Prof. Dr. Ing. Miroslav Fikar

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 2006.

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 then three 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 Assoc. 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 three-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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IV TEACHING AND RESEARCH LABORATORIES

IV.1 Teaching Laboratories

Laboratory of Process Control
Laboratory of Control Systems
Laboratory of Measuring Instruments and Techniques
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 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, Yokogawa)

V. EDUCATIONAL ACTIVITIES

V.1 Bachelor Study

1st semester (autumn)

Informatics	1/0/2	Hirmajer, Čižniar, Herceg, Líška, Pastoreková, Puna, Vaneková, Vasičkaninová, Závacká

2nd semester (spring)

Computer Based Data Processing	0/0/2	Čirka, Burian, Dermíšek, Karšaiová, Ondrovičová
Optimisation	3/3/0	Dvoran, Calík, Hirmajer, Ondrovičová, Pastoreková, Vasičkaninová

5th semester (autumn)

Computer Based Data Processing	0/0/2	Dermíšek, Karšaiová, Ondrovičová

6th semester (spring)

Automatic Control Fundamentals	2/0/0	Bakošová, Fikar
Laboratory Exercises of Automatic Control Fundamentals	0/0/2	Bakošová, Fikar, Karšaiová, Vasičkaninová, Puna, Závacká
Bachelor projects	0/0/4	Bakošová, Čirka, Fikar, Hirmajer, Puna

V.2 Master Study

1st semester (autumn)

Process Control	1/0/2	Bakošová, Karšaiová
Process Dynamics	2/0/0	Bakošová
Operating Systems	1/0/1	Fikar
Control Devices and Systems	2/0/1	Danko
Computer Programs	1/0/2	Čirka
Laboratory Project I	0/0/8	Bakošová, Čirka, Čižniar, Karšaiová

2nd semester (spring)

Optimisation	2/0/1	Dvoran
Control Theory I	2/0/2	Čirka, Mikleš
Laboratory Exercises of Control Theory I	0/0/2	Mikleš
Experimental Identification	2/0/0	Fikar
Laboratory Project II	0/0/6	Čirka, Danko, Dvoran, Mikleš, Ondrovičová
Modelling and Control of Polymerization Processes	2/0/2	Dvoran
Laboratory Exercises of Process Dynamics	0/0/1	Bakošová
Measurement of Process Variables	1/2/0	Čirka

3rd semester (autumn)

Control Theory II	2/0/0	Mikleš
Laboratory Exercises of Control Theory II	0/0/2	Mikleš
Intelligent Control Systems	2/0/0	Dvoran

CAD Systems	2/0/0	Karšaiová
Semestral Project	0/0/8	Čirka, Dvoran, Karšaiová, Vaneková
Industrial Applications of Process Control	2/0/0	Vaneková
Control of Technological Processes	1/0/2	Bakošová
Robust Control	2/0/0	Fikar

4th semester (spring)

Diploma Theses	0/0/27	Čirka, Fikar, Mikleš, Ondrovičová

V.3 PhD Study

1st semester (autumn)

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

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

Informatics (1h/week, 1st semester)

MS Windows 2000 operating system. MS Excel as a tool for data processing, data processing by tables, data visualization by graphs. MS Word – text processor. Internet.

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.

Automatic Control Fundamentals (2h/week, 6th semester)

Introduction to automatic control fundamentals. 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.

V.4.2 Lectures in Master study

Process Control (1h/week, 1st semester)

Introduction to process control. Various forms of mathematical description of linear continuous-time systems and their connections. Input-output differential equation, transfer function, frequency-response function, state-space equation and its solution, mathematical description of systems with time delays. Frequency responses of linear continuous-time systems, responses on arbitrary signals. Internal properties of linear continuous-time systems: stability, controllability, observability, properness, stabilisability. Stability of feedback control loops. Controller synthesis. Mathematical models of linear discrete-time systems. Discrete PID controller.

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

Fundamentals of chemical process modelling and simulation. Nonlinear and linearized models of serially connected tanks, the static and dynamic behaviour. Dynamic behaviour of processes with heat exchange: shell heat exchangers with ideal mixing of media, tube heat exchangers, co-current and counter-current cases. Dynamic behaviour of processes with material exchange: plate distillation columns, stuffed distillation columns, stuffed absorption columns. Dynamic behaviour of processes with chemical reactions: continuous-time stirred tank reactors, tube reactors without or with catalyst.

Operating Systems (1h/week, 1st 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.

Control Devices and Systems (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.

Computer Programs (1h/week, 1st semester)

MATLAB programming language: internal properties, variables, functions, data analysis, data visualization, data storing, programming in MATLAB. Simulink simulation language: simulation schemes, block parameter settings, simulation parameter setting, block libraries, s-functions. MATLAB/Control toolbox: simulation and control of systems. Origin – graphic software, data processing, data visualization, special functions. Word - text processor.

Optimisation (2h/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. Heuristic and learning methods, genetic algorithms. Linear, dynamic, nonlinear programming. Optimal and strategic decision-making. Large-scale optimisation tasks and their decomposition.

Control Theory I (2h/week, 2nd 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.

Experimental 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. Correlation methods of identification, stochastic signals, correlation functions. Wiener-Hopf equation and its using for identification. Filtration and prediction of signals. State estimation and observability – Lueneberg observer, Kalman filtration. Using of identification for modelling and control of technological processes.

Modelling and Control of Polymerization Processes (2h/week, 2nd semester)

Principles of modelling of processes of chemical technology. Analytical and experimental approaches to modelling. Identification of static models based on the least square method. Recursive identification of discrete dynamic models. Analysis of synthesis, modification and production of polymers from the measurement and control point of view. Analysis of fibre production from the measurement and control point of view. Analysis of tire production from the measurement and control point of view. Analysis of processes of polygraphic technology from the control point of view. Analysis of processes of pulp and paper technology from the control point of view.

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

Algebraic theory of linear control, mathematical basement. Using of algebraic theory for continuous-time and discrete controller design, pole-placement, dead beat. Adaptive control. Self-tuning adaptive systems, recursive identification. Continuous-time and discrete adaptive control. Model reference adaptive control systems (MRAS), principles, MRAS according to MIT, MRAS in the sense of Ljapunov theory of stability. Predictive control. Robust control, H_2 and H_∞ control.

Intelligent Control Systems (2h/week, 3rd semester)

Expert systems – knowledge based systems. Knowledge representation. Basic features of expert systems, structure and processing. Diagnostic expert systems. Planning expert systems. Expert systems based on rules, frames and logical programming. Programming tools for expert systems – programming languages LISP and PROLOG. Fuzzy systems. Basic principles of fuzzy sets and fuzzy logic. Fuzzy decision processes, fuzzy modelling and identification. Design procedures for fuzzy logic controllers. Rule based fuzzy controllers, model based fuzzy controllers. Neural nets. Basic principles of artificial neural nets (ANS). Representation of dynamic systems using feed-forward and feedback neural nets. System identification based on using of neural nets. Parameter estimation and neural net training. Controllers based on using of neural nets. Adaptive control based on using of neural nets, direct and non-direct. Genetic control algorithms. Control of textile production.

CAD Systems (2h/week, 3rd semester)

Classification of automatic control systems, types of control algorithms. Automatic control system design. Feedback control loops – simple, composed. Control loops for flow rate, pressure, level control. Control loops for heat exchangers, distillation, absorption, extraction columns, batch and continuous-time chemical reactors. MIMO control of distillation columns. Large-scale systems – analysis, modelling and control.

Industrial Application of Process Control (2h/week, 3rd semester)

Introduction to industrial application of process control. Problems connected with control system design and control system application in practice. Hardware and software of industrial control systems, programming of industrial automata, data processing and visualization. Control of a chemical reactor for a decomposition of H_2O_2. Control of a binary plate distillation column. Solving of control problems for chemical industry.

Control of Technological Processes (1h/week, 3rd semester)

The course is given for students of specialization Organic Technology and Petrochemistry. Course content is following. Introduction to control of technological processes. Principles of control of technological processes: feedback and feedforward control. Simple feedback control loop. Methods for PID controller synthesis. 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.

V.4.3 Laboratory exercises in Bachelor study

Informatics (2h/week, 1st semester)

MS Windows 2000 operating system. MS Excel as a tool for data processing, data processing by tables, data visualization by graphs. MS Word – text processor.

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 Automatic Control Fundamentals (2h/week, 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.

V.4.4 Laboratory exercises in Master study

Laboratory Exercises of Control Theory I (2h/week, 2nd semester)

Simulation of pole-placement method. State-space approach. State observer design for simple systems. Simulation of state feedback. Simulation of feedback control with a state observer. Design of a set of stabilizing controllers for simple systems. Simulation of MIMO feedback systems by using of stabilizing controllers. Simulation of feedback control by using of a LQ controller for simple serially connected tanks and for a chemical reactor. Synthesis of a PI controller, PI controller design by LQ method. Simulation comparison of a classic and a LQ PI controllers. Simulation of LQ control with deterministic state estimation. LQG state controller. Simulation of feedback control by a state-space LQG controller. LQG input-output controller. Adaptive control. Closed-loop identification. Closed-loop recursive identification. Simulation of adaptive control with recursive identification and with LQ/LQG controller. Adaptive control of serially connected tanks, adaptive control of a chemical reactor.

Laboratory Exercises of Process Dynamics (1h/week, 2nd semester)

Simulation of dynamic behaviour of systems in MATLAB/Simulink. Analysis and simulation of static and dynamic behaviour of a system of serially connected tanks with/without interactions. Analysis and simulation of static and dynamic behaviour of a tube heat exchanger as a continuously distributed parameter system. Transformation of a system of partial differential equations to a system of ordinary differential equations by discretization. Calculation of a steady-state of a plate distillation column, analysis and simulation of static and dynamic behaviour of a plate distillation column as a discretely distributed parameter system. Analysis and simulation of static and dynamic properties of an exothermic continuous-time stirred tank reactor. Calculation of steady state of a chemical reactor, steady-state analysis of a chemical reactor, linearization of nonlinear models.

Laboratory Exercises of Control Theory II (2h/week, 3rd semester)
Algebraic theory of linear control. Control of the 2nd order continuous-time system by discrete controller. Self-tuning adaptive control system for the 2nd order linear system, discrete and hybrid approach. Model reference adaptive control (MRAC). Adaptation of static gain. MRAC for the 1st and 2nd order systems. MRAC in the sense of the Ljapunov theory of stability, application on the 1st order system. Predictive control.

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

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

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.

2. System Identification (J. Mikleš, M. Fikar, Ľ. Čirka)

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:

a) nonparametric methods, correlation and spectral analysis
b) recursive identification of Z-transform discrete-time models
c) recursive identification of delta models which converge to their continuous-time counterparts
d) 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.

3. Optimal Control Design (J. Mikleš, M. Fikar, M. Kvasnica, L. Dermíšek)

The main aim of this area is to develop a package of algorithms and program implementation of various known control designs for given plants. 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/Simulink environment.

4. Adaptive Controllers (J. Mikleš, M. Bakošová, Ľ. Čirka, M. Fikar)

Most of technological plants exhibit non-linear behaviour. To apply a successful control design to practical problems is a substantial effort. It is known that processes are 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 four main areas as follows:

a) self-tuning control - characterized by repeating parameter estimation and control design
b) model reference adaptive control based on the Ljapunov method
c) decentralized adaptive control
d) adaptive lambda-tracking

5. Neural Networks (A. Mészáros, L. Pastoreková)

The aim of this research is to investigate 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.

6. Fuzzy Control and Expert Systems (J. Dvoran, A. Vasičkaninová, P. Líška)

The aim of this research is to investigate fuzzy and neuro-fuzzy controllers. The usefulness of fuzzy control can be considered in two

aspects. First, control offers a novel mechanism to implement such control laws that are often knowledge-based or even in linguistic descriptions. Second, fuzzy control provides an alternative methodology to facilitate the design of nonlinear controllers for such controlled plants that art uncertain and very difficult to cope with conventional nonlinear theory.

7. Predictive Control (M. Fikar, M. Kvasnica, M. Herceg)

Predictive control 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 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 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 the research is focused on predictive control of hybrid systems, i.e. systems that combine continuous dynamics with the aspects of discrete transitions, such as on/off switches or finite state automata. Algorithms, which provide stability guarantees for such class of systems, are being developed and tested on real devices.

8. Dynamic Optimisation (M. Fikar, M. Kvasnica, K. Calík, M. Čižniar, T. Hirmajer)

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 are studied.

9. Robust Control (J. Mikleš, M. Bakošová, D. Puna, K. Vaneková, J. Závacká)

Robustness has been recognized as a key issue in the analysis and design of control systems for the last two decades. Processing of chemical reactors, heat exchangers, distillation columns, etc. is connected with many different uncertainties. Some of them arise from varying or not exactly known parameters, as e.g. chemical kinetics or reaction activity. In other cases operating points change. The processes are also affecting by various types of perturbations. All these uncertainties can cause poor

performance or even instability of closed-loop control system. Application of robust control approach can be one of the possibilities how to overcome all these problems. One of the up to now opened problems is also the problem of a robust static output, which is studied.

10. Process Control

The research of all research groups is focused on control applications for various types of chemical and biochemical processes.

11. Control Engineering Education (M. Fikar, Ľ. Čirka, M. Bakošová, T. Hirmajer)

The research in control engineering education has been oriented on use of new information technologies in control engineering education, interactive on-line courses and automatic generation of test problems. The task of personification of a web page for students and teachers is solved recently.

12. Information Technologies (M. Fikar, Ľ. Čirka, T. Hirmajer, D. Puna)

The research in information technologies has been oriented on

a) use of information technologies for data manipulation, retrieval, and visualization,
b) development of static and dynamic web pages not only for use in control and measurement, but also for general information and data management.

Technologies are based on open-source projects like Apache, MySQL, PHP, etc.

VI.2 Research Projects in Slovak Republic

1. VEGA Project No 1/1046/04: Progressive methods of adaptive and intelligent control applied to processes of chemical/biochemical technologies (A. Mészáros)

The problem of applications of modern control techniques for industrial biochemical processes is investigated. This effort is often hampered by the lack of adequate mathematical models and tools as well as the absence of on-line sensors and monitoring devices. Consequently, in comparison with traditional chemical industrial processes the fermentation and other biochemical processes still hold a backward position in respect of the application of modern control techniques. The main goals of the project can be listed as follows:

- Analysis of methods and algorithms for recursive identification of simplified experimental and analytical models of biochemical processes for simulation and control purposes.
- Design, testing and comparison of intelligent and robust controllers, non-adaptive and adaptive ones, for biochemical reactors and other plants of biochemical technology with final aim of their direct computer control.
- Development and verification of modern integrated optimising algorithms, suitable for the optimising layer of the hierarchical multilayer control structure.
- Development of software package based on artificial neural networks for modelling and control strategies at adaptation and organization layers of the hierarchical control structure.
- Implementation of principles of fuzzy control, neuro-fuzzy control and decentralized control to control structures for biochemical and chemical processes.
- Accomplishment of computer based control system for a laboratory fermenter LF-3 including implementation of industrial visualization software for process monitoring and control.
- Data acquisition and processing, utilizing software filters on the fermenter LF-3; Estimation of state variables in the fermenter (substrate, biomass and byproduct concentrations) on the basis of neural network approach using the measured data (dissolved oxygen concentration, pH, gas phase composition, stirring speed, etc.) as training sets.
- Implementation of the developed identification algorithms and control structures in control of the laboratory fermenter.
- Transfer and adaptation of the results and experience, gained through simulation and laboratory experiments to industrial circumstances, especially those ones involved in citric acid and baker's yeast production as well as in alcoholic fermentation processes.

In the frame of this project, several important results were obtained. The capability of self-recurrent neural networks in dynamic modelling of continuous fermentation was investigated. Further, a constrained predictive control strategy using artificial neural networks (ANN) was designed. The recurrent ANN is used as a multi-step ahead predictor. The control action is provided by the multilayer feedforward ANN.
Period: January 2004 – December 2006

2. VEGA Project No 1/3081/06 Optimisation and Control of Chemical and Biochemical Processes (M. Fikar)

The project deals with development of modern control and optimisation methods and focuses into processes typical in chemical and food industries: chemical reactors, distillation columns, waste-water treatment plants, and others. Involves static and dynamic, and global optimisation methods, predictive control as well as supervisory control. Developed algorithms, controllers, and control structures will be tested by simulations and in laboratory conditions.

Scientific goals for the first period of this project:

- Bibliography research in the investigated field.
- Connection of laboratory processes to the control systems dSPACE and Siemens.
- Modelling and simulation of hybrid (mixed continuous/discrete) systems.
- Analysis and design of control and optimisation of hybrid systems.
- Dynamic optimisation of a continuous and hybrid processes systems and with special attention to bioreactors and wastewater treatment plants.
- Design of a software package for simulation and dynamic optimisation of hybrid systems.
- Interface of the software package DYNO with MATLAB.
- Global dynamic optimisation – study of existing approaches.
- Design of supervisory control with industrial control systems.
- Design of a software package for multiparametric optimisation and explicit predictive control

Scientific goals for the second period of this project:

- Control design of ASP processes modelled by hybrid models. Comparison and analysis of the results, recommendations for practical implementation of WWTP plants control.
- Implementation of the software package for dynamic optimisation of hybrid systems. Intranet connection and remote control of laboratory processes controlled by the dSPACE and Siemens Simatic S7 300 systems.
- Intranet connection and remote control of laboratory processes controlled by the dSPACE and Siemens Simatic S7 300 systems.
- Application of theoretical results in control and optimisation on the laboratory processes: chemical reactor, distillation columns, heat exchanger, and liquid storage tanks.

- Transfer of the theoretical and experimental results into industrial conditions and demonstration of the advantages of the modern control methods in Slovak chemical and food industries.

Period: January 2006 - December 2008

VI.3 International Scientific Programs

1. Project of French National Science Foundation Polynomial optimisation of complex systems ECO-NET (Miroslav Fikar)

The project investigates the possibility to use the newest results in polynomial methods and linear matrix inequalities developed in LAAS-CNRS Toulouse for solution of various problems: robust control (CTU Prague), control of chaotic systems (ITIA Prague), predictive control (STU Bratislava), nonlinear control (IMPRE, Sankt Peterburg). The cooperation enables to spread the field of applications and the partners become familiar with the latest progress in theoretical and practical aspects of polynomial optimisation.

Participants: Department of Information Engineering and Process Control, FCFT STU, Bratislava, Slovakia; LAAS-CNRS Toulouse, France, CTU Prague, Czech Republic, ITIA Prague, Czech Republic, IMPRE, Sankt Peterburg, Russia

Period: January 2006 – December 2007

2. Project of Slovak – Czech Scientific Cooperation No SK-CZ 11206 Progressive robust and adaptive control methods for processes with heat and mass transfer (Monika Bakošová)

The project deals with development of progressive approaches to control of systems with uncertainties and focuses on processes with heat and mass transfer typical for chemical and food technologies, as e.g. distillation columns, heat exchangers, chemical reactors and others. Development of methods of robust analysis, robust stabilization and robust control of systems with uncertainties constitutes the core of the project. Modern adaptive control methods are investigated as well. Designed algorithms and control structures are tested by simulations and on laboratory processes.

Participants: Department of Information Engineering and Process Control, FCFT STU, Bratislava, Slovakia; Faculty of Applied Informatics, Tomas Bata University, Zlín, Czech Republic

Period: January 2006 – December 2007

3. Project of Slovak – Czech Scientific Cooperation No SK-CZ 11106 Advanced control methods for processes of chemical and food technologies (Miroslav Fikar)

The aim of the project is to develop advanced methods for control and optimisation of processes in chemical and food technology, e.g. chemical reactors, distillation columns, sludge processes, etc. Methods of dynamic and global optimisation, predictive control and multistage control design are investigated. Developed control algorithms, controllers and control structures are tested by simulations and in laboratory conditions.

Participants: Department of Information Engineering and Process Control, FCFT STU, Bratislava, Slovakia; Faculty of Technology, University of Pardubice, Pardubice, Czech Republic

Period: January 2006 – December 2007

4. Project of Slovak – Hungarian Scientific Cooperation No 21 Modelling and Control of Modern Processes with Heat and Mass Transfer (Alojz Mészáros)

With regard to ongoing research projects at the two partner departments, 3 research areas can be selected for future scientific collaboration. They are:

- Chemical Process Modelling and Control
- Integrated Process Design
- Hybrid Separation Process Design

Research workers of the Dept. Of Chemical Engineering of BUTE are well experienced in chemical engineering of unit operations, steady state modelling and process design, while the research team of the Department of Information Engineering and Process Control of STU has good knowledge and experience in process dynamic modelling and control system design. This proposed collaboration enables to mutually utilize the know-how of the two teams in order to create more beneficial research outcomes, like adaptive and intelligent chemical process control systems based on methods of artificial intelligence.

The collaboration is planned to be conducted in two phases:

I. Continuation and completion of research activities on the following topics:
- Separation processes for non-ideal mixtures
- Analysis, simulation and control of hybrid separation processes
- Adaptive control of separation processes
- Modelling and dynamic analysis of a multicolumn distillation process
- Publication of the results obtained

II. Modification and extension of the above topics as follows:
- Process modelling using artificial neural networks (ANN)
- Adaptive process control design using ANN
- Robust intelligent control design
- Adaptive lambda-tracking control design
- Testing of the proposed new algorithms for nonlinear chemical processes through simulation experiments
- Application of adaptive control for separation processes
- Implementation of computer control for laboratory fermenter
- Publication of the results obtained

Participants: Department of Information Engineering and Process Control, FCFT STU, Bratislava, Slovakia; TU Budapest, Hungary.

Period: January 2005 – December 2006

VI.4 Educational Projects in Slovak Republic

1. KEGA Project No 3/3121/05 Network of virtual laboratories for control of real systems (Miroslav Fikar)

The aim of the project is to create an open network of virtual laboratories in Slovakia connected together via Internet and to laboratory networks abroad. The project will also implement and test properties of centralised network managed by an educational portal and distributed network created from servers on the participant's laboratories.

Participants: Department of automation and regulation, FEI STU, Bratislava, doc. Huba (coordinator), DIEPC FCHPT STU, doc. Fikar, Department of Computers and Informatics, FEI TU Košice, Ing. Jakab

Period: January 2005 – December 2007

2. ESF Project No 13120110014 Program of continuing education in industrial automation and information technologies (Miroslav Fikar)

The aim of the project is to realize various courses in industrial automation and information technologies for support of employment.

Participants: DIEPC FCPT STU (coordinator), doc. Fikar, Department of Automation and Regulation, FEI STU, doc. Huba, Department of Automation and Regulation, SjF STU, Prof. Rohaľ-Ilľkiv

Period: January 2005 – December 2007

3. ESF Project Development of human resources for research in the field of automation (Miroslav Fikar)

The main aim of the project is to improve quality of employment of Bratislava region using development of human resources in research. Project should enforce regional research in automation, to create and develop learning society and network connected to national and international communities, to transfer the newest knowledge from academia to industry, and to increase awareness of enterprises about the research potential in the region.

Participants: Slovak e-Academy, doc. Huba (coordinator), DIEPC FCPT STU, doc. Fikar, Department of Automation and Regulation, SjF STU, prof. Rohaľ-Ilľkiv

Period: January 2004 – December 2006

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

Department of Automation and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology, Bratislava

Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Košice

Department of Management and Control Engineering, BERG Faculty, Technical University of Košice, Košice

Siemens, Inc., Bratislava

ProCS, Ltd., Šaľa

VII.2 International Cooperation

Department of Process Control and Computer Techniques, Faculty of Chemical Technology, University of Pardubice, Pardubice, Czech Republic

- Advanced control methods for processes of chemical and food technologies

Department of Computing and Control Engineering, Institute of Chemical Technology, Prague, Czech Republic

- Control of biochemical processes

Faculty of Applied Informatics, Tomas Bata University, Zlín, Czech Republic

- Adaptive control
- Robust control
- Decentralized control

Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic, Prague, Czech Republic

- Polynomial methods
- Predictive control

Faculty of Electrical Engineering, Czech Technical University, Prague, Czech Republic

- Polynomial methods
- Predictive control

LSGC-CNRS, Ecole Nationale Superieure des Industries Chimiques (ENSIC), Nancy, France

- Dynamic optimisation of distillation columns
- Waste-water treatment plants

Ecole Nationale Superieure des Ingenieurs de Genie Chimique-Chemin de la Loge (ENSIGC), Toulouse, France

- Polynomial methods

Ruhr University, Bochum, Germany

- Closed-loop identification
- Predictive control
- E-learning in control

University of Technology and Economics, Budapest, Hungary

- Modelling of chemical processes

VII.3 Membership in Domestic Organizations and Societies

Slovak Society for Cybernetics and Informatics, Bratislava (J. Dvoran, A. Mészáros, J. Mikleš)

Slovak Society of Chemical Engineering (M. Bakošová, J. Dvoran., A. Mészáros, J. Mikleš)

Slovak Society of Industrial Chemistry (M. Bakošová, Ľ. Čirka, J. Danko, L. Dermíšek, J. Dvoran, M. Fikar, M. Karšaiová, A. Mészáros, J. Mikleš, M. Ondrovičová, A. Vasičkaninová)

Scientific Grant Agency VEGA MŠSR a SAV - Commission for Elektrotechnics and Informatics (J. Mikleš)

Commission for defence of dissertations (DSc) at science 28-30-9 Chemical Engineering and Process Control (J. Mikleš)

Commission for defence of dissertations (DSc) at science 38-01-9 Automation and Control (J. Mikleš - chairman)

Common branch commission for PhD study at science 28-30-9 Chemical Engineering and Process Control (J. Mikleš – vice-chairman, M. Bakošová, J. Danko, J. Dvoran, M. Fikar, A. Mészáros)

Common branch commission for PhD study at science 38-01-9 Automation and Control (J. Mikleš)

Common branch commission for the field of study 5.2.14 Automation and Control (M. Bakošová, J. Dvoran, M. Fikar, A. Mészáros, J. Mikleš)

Editorial board of AT&P Journal (J. Dvoran, A. Mészáros, J. Mikleš)

Editorial board of Cybernetics and Informatics (J. Mikleš)

VII.4 Membership in International Organizations and Societies

International Federation of Automatic Control, Technical Committee on Control Design (J. Mikleš)

International Federation of Automatic Control (IFAC), Slovak National Member Organization (Slovak NMO) (J. Mikleš)

European Federation of Biotechnology (A. Mészáros)

The New York Academy of Sciences (A. Mészáros)

Public Board of the Hungarian Academy of Sciences (A. Mészáros)

Czech Society of Chemical Engineering (M. Bakošová, A. Mészáros)

EUCA (European Union Control Association) Council (M. Fikar)

VIII. THESES AND DISSERTATIONS

VIII.1 Graduate Theses (Bc Degree)

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

Beňová, G. Cascade control of a laboratory fan heater. (Bakošová, M.)

Hudý, S. Design of dynamic HTML documents. (Čirka, Ľ.)

Lanák, R.	Creation of dynamic HTML forms with the help of PHP and MySQL. (Hirmajer, T.)
Paulen, R.	Control of time-delay systems. (Bakošová, M.)
Šlapanský, P.	Creation of the LCZA module in the e-learning system MOODLE. (Hirmajer, T.)
Švančarová, Z.	Dynamic HTML pages. (Puna, D.)
Zika, R.	Modelling and control of dynamical systems in MATLAB/Simulink. (Čirka, Ľ.)

VIII.2 Graduate Theses (MS Degree)

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

Herceg, M.	Nonlinear model predictive control of a diesel engine with exhaust gas recirculation and variable geometry turbocharger. (Fikar, M.)
Petruš, P.	Identification toolbox for MATLAB/Simulink. (Čirka, Ľ.)
Stolárik, I.	Optimisation of a CSTR. (Mikleš, J.)
Šátková, B.	E–learning module for laboratory exercises of Process Control Fundamentals. (Čirka, Ľ.)
Ševčík, Š.	Dynamic optimisation of processes. (Fikar, M.)
Vaneková, K.	Control by control system Simatic. (Ondrovičová, M.)

VIII.3 Inauguration Theses

Fikar, M. Control of Processes with Constraints.

IX. PUBLICATIONS

IX.1 Journals

(* registered in Current Contents)

[1]* Hirmajer, T., Fikar, M.: Optimal Control of a Two-Stage Reactor System. Chemical Papers, No. 5, Vol. 60, pp. 381-387, 2006.

[2] Hirmajer, T., Fikar, M.: Dynamic Optimisation of a Hybrid Coupled Tanks System. Journal of Electrical Engineering, No. 3, Vol. 57, pp. 167–172, 2006.

[3] Hirmajer, T., Fikar, M.: Optimal control of a reactor system (in Slovak). AT&P Journal, No. 11, Vol. 13, pp. 69-72, 2006.

[4] Vasičkaninová, A., Bakošová, M., Dvoran, J.: Neuro-fuzzy modelling using Anfis method (in Slovak). AT&P journal, No. 11, Vol. 13, pp. 73-76, 2006.
[5] Vasičkaninová, A., Bakošová, M., Dvoran, J.: Cascade control of a chemical reactor using Fuzzy controllers (2) (in Slovak). AT&P Journal, No. 1, Vol. 13, pp. 65-66, 2006.
[6] Závacká, J., Bakošová, M., Puna, D.: Robust control of a chemical reactor (in Slovak). AT&P journal, No. 11, Vol. 13, pp. 65-68, 2006.

IX.2 Conferences

(* International conferences)

[1]* Bakošová, M, Puna, D, Závacká, J: Robust control of a chemical reactor using static output feedback. In: Proc. 17. Int. Congress of Chemical and Process Engineering CHISA 2006, Process Engineering Publisher, CDROM- 0816, 2006.
[2]* Bakošová, M., Baleja, J., Vasičkaninová, A.: MODELTOOL 1.0 - a model toolbox for MATLAB/Simulink. Editors: Troch, I., Breitenecker, F. In: Proc. 5th MATHMOD Vienna, AGRESIM - Verlag, Vienna, 2006, Vienna, Austria, Vol. 1, pp. 347, 2006.
[3]* Bakošová, M., Baleja, J., Čirka, Ľ.: MODELTOOL 1.0 - a Model Toolbox for MATLAB/Simulink. In: 14th Annual Conference Proceedings: Technical Computing Prague 2006, pp. 12-12, 2006.
[4]* Bakošová, M., Baleja, J., Vasičkaninová, A.: MODELTOOL 1.0 – A MODEL TOOLBOX FOR MATLAB/SIMULINK. Editor: Krejčí, S. In: Proc. 7. Int. Scientific-Technical Conf. Process Control 2006, University of Pardubice, Kouty nad Desnou, Czech Republic, CD ROM R074a-1 - R074a-5, 2006.
[5]* Bakošová, M., Puna, D., Mészáros, A.: Control of a continuous-time stirred tank reactor via robust static output feedback. In: Prep. 14th Mediterranean Conference on Control and Automation, Ancona, Italy, CD ROM TM5-5, 2006.
[6]* Bakošová, M., Puna, D., Závacká, J., Ondrovičová, M.: ROBUST CONTROLLER DESIGN OF A CHEMICAL REACTOR USING LMIs. Editor: Krejčí, S. In: Proc. 7. Int. Scientific-Technical Conf. Process Control 2006, University of Pardubice, Kouty nad Desnou, Czech Republic, CD ROM R074b-1 - R074b-11, 2006.
[7]* Burian, P., Mészáros, A., Pastoreková, L.: Adaptive control of a reactor - column system. In: Proc. 7. International Scientific - Technical Conference PROCESS CONTROL 2006, Kouty nad Desnou, Czech republic, CD-ROM: R007.pdf, 2006.

[8]* Dermíšek, L., Mikleš, J., Vöröš, J., Čirka, Ľ.: Continuous Stirred Tank Reactor Optimising. In: Proceedings of 7th International Carpathian Control Conference, Ostrava, Czech Republic, 2006.
[9]* Dermíšek, L., Mikleš, J., Vöröš, J., Čirka, Ľ.: Static Optimisation of the Continuous Stirred Tank Reactor. In: Proceedings of 7th International Scientific-Technical Conference PROCESS CONTROL 2006, Kouty nad Desnou, Czech Republic, CD-ROM R168-1-12, 2006.
[10]* Čirka, Ľ., Fikar, M., Mikleš, J.: Adaptive LQ Control of a Laboratory Fan Heater. Editor: Krejčí, S. In: Proc. 7. International Scientific-Technical Conf. Process Control 2006, University of Pardubice, Kouty nad Desnou, Czech Republic, CD ROM R004b-1 - R004b-12, 2006.
[11]* Čirka, Ľ., Fikar, M., Petruš, P.: IDTOOL 4.0 - A Dynamical System Identification Toolbox for MATLAB/Simulink. In: 14th Annual Conference Proceedings: Technical Computing Prague 2006, pp. 29-29, 2006.
[12]* Čižniar, M., Fikar, M., Latifi, M.A.: A Matlab Package for Dynamic Optimisation of Processes. In: Proc. 7. International Scientific-Technical Conf. Process Control 2006, University of Pardubice, Kouty nad Desnou, Czech Republic, CD-ROM R118.pdf, 2006.
[13]* Fikar, M., Valo, R., Čirka, Ľ., Bakošová, M., Dvoran, J.: Individualized approach in Automatic Control Fundamentals education (in Slovak). In: Principia Cybernetica 2006, FAI UTB, Zlín, Czech Republic, CDROM P4-21 - P4-28, 2006.
[14]* Fikar, M., Valo, R., Čirka, Ľ., Bakošová, M., Huba, M.: Individualised Approaches in Control Education Courses with Large Number of Students. Editor(s): S. Dormido, A. Fernandez, F. Morilla, R. Pastor, In: Preprints of the 7th IFAC Symposium on Advances in Control Education, Madrid, CD-ROM 78.pdf, 2006.
[15]* Herceg, M., Raff, T., Findeisen, R., Allgower, F.: Nonlinear Model Predictive Control of a Turbocharged Diesel Engine. In: Proc. of the 2006 IEEE International Conference on Control Applications, Munich, Germany, pp. 2766-2771, 2006.
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[17]* Hirmajer, T., Fikar, M.: Optimal Control of a Two-stage Reactor System. Editor: Krejčí, S., In: Proc. 7. International Scientific-Technical Conference Process Control 2006, University of Pardubice, Kouty nad Desnou, Czech Republic, CDROM AR021, 2006.
[18]* Huba, M., Kamenský, M., Bisták, P., Fikar, M.: Blended Learning Course: Constrained PID Control. Editor(s): S. Dormido, A. Fernandez,

F. Morilla, R. Pastor, In: Preprints of the 7th IFAC Symposium on Advances in Control Education, Madrid, CD-ROM 161.pdf, 2006.

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[34] Puna, D., Bakošová, M., Mészáros, A., Závacká, J.: CONTROL OF A CHEMICAL REACTOR WITH UNCERTAINTIES IN AN UNSTABLE STEADY STATE. Editors: Markoš, J., Šefuca, V., In: Proc. 33rd Int. Conf. SSCHE, SSCHE Bratislava, Tatranské Matliare, Slovakia, CDROM 045p, 2006.
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IX.3 Reports

[1] Čižniar, M., Fikar, M., Latifi, M.A.: MATLAB Dynamic Optimisation Code DYNOPT. User's Guide. Bratislava, 2006.
[2] Hirmajer, T., Fikar, M.: Optimal Control of a Hybrid Dynamical System: Two-stage Reactor System. FCFT STU, Radlinského 9, 812 37 Bratislava, Slovakia, 2006.