SLOVAK UNIVERSITY OF TECHNOLOGY

FACULTY OF CHEMICAL TECHNOLOGY

DEPARTMENT OF PROCESS CONTROL

ANNUAL REPORT

2000

Address:

Department of Process Control
Faculty of Chemical Technology
Slovak University of Technology
Radlinského 9
812 37 Bratislava
Slovak Republic

Telephone: ++ 421 – 7 – 52 49 52 69
Fax: ++ 421 – 7 – 52 49 64 69
Web: http://www.ka.chtf.stuba.sk

I PREFACE

Department of Process Control has at the Faculty of Chemical Technology of the Slovak University of Technology almost forty-year tradition. In the frame of the study branch Chemical Engineering and Process Control on the specialisation Process Control, it educates high-qualified specialists in the field of process control for design, implementation and processing of control systems.

Nowadays, process control with using microprocessor based control technique represents important and acknowledged scientific branch. This branch more and more influences the economic and social growth in the whole world and successively also in our country. The chemical, food and pharmaceutical industry with their technologies are no exceptions. No technology is able to be successful in the competition without optimisation and advanced control systems. 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 process control has been very attractive and its significance is even growing. The graduates of the department do well not only in the firms 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 apparatuses and equipment, automatic analysers and on development of software packages for intelligent control systems.

Prof. Ján Mikleš, PhD., DSc.

II INTRODUCTION

This report summarises the teaching and research activities at the Department of Process Control at the Faculty of Chemical Technology at the Slovak University of Technology during the period 1 January – 31 December 1999.
Department of Process Control of the Faculty of Chemical Technology of the Slovak University of Technology was constituted from the Department of Measuring and Control Technique of the Faculty of Electrical Engineering of the Slovak Technical University in 1962. Because of the specific control problems of the processes and systems in the chemical and biochemical technology, the specialisation 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 two professors and eight associated professors have been appointed.
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. The head in 1995 – 1997 was Alojz Mészáros, PhD. and Prof. Ján Mikleš, PhD., DSc. has again headed the department since 1998.
Department of Process Control is one of the 22 departments at the FCT STU, where the students obtain specialisation in various branches of chemical technology or chemical engineering. Approximately 1000 students are currently enrolled in the five-year program leading to the Ing. degree, which is equivalent to the M.S. degree.

III STAFF

Head of the Department:

Prof. Ján Mikleš, PhD, DSc.
Telephone: ++ 421 – 7 – 59 325 343
E-mail: mikles@cvt.stuba.sk

Full Professor:

Ján Mikleš, PhD, DSc.
Telephone: ++ 421 – 7 – 59 325 343
E-mail: mikles@cvt.stuba.sk
Closed-loop identification, adaptive control, robust control

Associate Professors:

Monika Bakošová, PhD
Telephone: ++ 421 – 7 – 59 325 353
E-mail: bakosova@chtf.stuba.sk
Decentralised adaptive control, lambda-tracking, process modelling and control

Ján Danko, PhD
Telephone: ++ 421 – 7 – 59 325 352
E-mail: danko@chtf.stuba.sk
Real process control

Ján Dvoran, PhD
Telephone: ++ 421 – 7 – 59 325 345
E-mail: dvoran@cvt.stuba.sk
Expert systems, fuzzy control, genetic algorithms

Miroslav Fikar, PhD
Telephone: ++ 421 – 7 – 59 325 354
E-mail: fikar@cvt.stuba.sk
Predictive control, identification, dynamic optimisation

Alojz Mészáros, PhD
Telephone: ++ 421 – 7 – 59 325 159
E-mail: ameszaro@cvt.stuba.sk
Neural nets, modelling and control of biochemical processes

Assistant Professors:

Ľuboš Čirka
Telephone: ++ 421 – 7 – 59 325 355
E-mail: cirka@chtf.stuba.sk
Identification, adaptive control

Mária Karšaiová, PhD	Telephone: ++ 421 – 7 – 59 325 362 E-mail: karsai@chtf.stuba.sk Control of large-scale systems
Magdaléna Ondrovičová	Telephone: ++ 421 – 7 – 59 325 353 E-mail: ondrovic@chtf.stuba.sk Closed-loop identification, control of distillation columns
Andrej Seč	Telephone: ++ 421 – 7 – 59 325 364 E-mail: sec@cvt.stuba.sk Control of stuffed columns
Anna Vasičkaninová	Telephone: ++ 421 – 7 – 59 325 348 E-mail: vasickan@chtf.stuba.sk Fuzzy and neuro-fuzzy control, time-delay systems
Anna Zemanovičová, PhD	Telephone: ++ 421 – 7 – 59 325 730 E-mail: zeman@chtf.stuba.sk Time-delay systems. fuzzy control

PhD students:

Anton Andrášik	Telephone: ++ 421 – 7 – 59 325 364 E-mail: andrasik@chtf.stuba.sk Control of biochemical processes
Jozef Dzivák	Telephone: ++ 421 – 7 – 59 325 351 E-mail: jdz@chtf.stuba.sk Nonlinear systems, control of chemical reactors
František Jelenčiak	Telephone: ++ 421 – 7 – 59 325 349 E-mail: jelen@chtf.stuba.sk Control of chemical reactors, nonlinear systems
Štefan Kožka	Telephone: ++ 421 – 7 – 59 325 351 E-mail: kozka@chtf.stuba.sk Closed-loop identification
Michal Kvasnica	Telephone: ++ 421 – 7 – 59 325 355 E-mail: kvasnica@chtf.stuba.sk

Optimal feed-back control, linear matrix inequalities, robust control

Technical staff:

Eva Fuseková
Telephone: ++ 421 – 7 – 59 325 366
E-mail: fusekova@chtf.stuba.sk

Andrea Kalmárová
Telephone: ++ 421 – 7 – 59 325 363
E-mail: kalmar@chtf.stuba.sk

Diana Lázničková
Telephone: ++ 421 – 7 – 59 325 349
E-mail: malejcik@chtf.stuba.sk
Fuzzy control

Anna Širicová
Telephone: ++ 421 – 7 – 59 325 363
E-mail: siricova@chtf.stuba.sk

IV TEACHING AND RESEARCH LABORATORIES

IV.1 Teaching Laboratories:

Laboratory of Measuring Instruments and Techniques
Laboratory of Process Control
Laboratory of Gas Analysis
Computer Laboratory (PC 486, Pentium)
Computer Laboratory (LINUX)

IV.2 Research Laboratories:

Laboratory of Biochemical Process Analysis and Control
Laboratory of Chemical Reactor Analysis and Control
Laboratory of Distillation Column Analysis and Control
Laboratory of Computer Aided Design
Laboratory of Modelling and Simulation

V. EDUCATIONAL ACTIVITIES

V.1 Undergraduate Study

2nd semester (spring)

Informatics	(1-2 h)	Ondrovičová, Vasičkaninová

5th semester (autumn)

Computer Based Data Processing	(0-2 h)	Čirka, Dzivák, Jelenčiak, Fikar, Karšaiová, Kožka, Ondrovičová, Seč, Vasičkaninová

6th semester (spring)

Automatic Control Fundamentals	(2-0 h)	Danko, Mészáros
Laboratory Exercises of Automatic Control Fundamentals	(0-2 h)	Andrášik, Bakošová, Čirka, Danko, Dzivák, Jelenčiak, Karšaiová, Seč, Ondrovičová, Vasičkaninová, Zemanovičová
Bachelor projects		Bakošová, Dvoran, Karšaiová, Mészáros, Mikleš, Ondrovičová, Seč, Vasičkaninová, Zemanovičová

7th semester (autumn)

Process Control	(1-2 h)	Mészáros
Process Dynamics	(2-0 h)	Bakošová
Operating Systems	(1-1 h)	Seč
Control Devices and Systems	(2-1 h)	Danko
Computer Programs	(1-2 h)	Fikar
Laboratory Projects	(0-8 h)	Fikar, Karšaiová, Mikleš, Seč, Vasičkaninová

8th semester (spring)

Optimisation	(2-1 h)	Dvoran
Control Theory I	(2-2 h)	Mikleš
Laboratory Exercises of Control Theory I	(0-2 h)	Čirka, Kožka
Experimental Identification	(2-0 h)	Mikleš
Laboratory Project II	(0-6 h)	Čirka, Dvoran, Mészáros, Mikleš
Modelling and Control		

of Polymerisation Processes	(2-2 h)	Dvoran
Process Dynamics	(2-0 h)	Bakošová
Laboratory Exercises		
of Process Dynamics	(0-1 h)	Bakošová

9th semester (autumn)

Control Theory II	(2-0 h)	Mészáros
Laboratory Exercises		
of Control Theory II	(0-2 h)	Mészáros
Intelligent Control Systems	(2-0 h)	Dvoran
Semestral Project	(0-10 h)	Dvoran, Karšaiová, Mészáros, Mikleš, Ondrovičová
CAD Systems	(2-0 h)	Karšaiová
Industrial Applications		
of Process Control	(2-0 h)	Mikleš
Control of Technological		
Processes	(1-2 h)	Bakošová

10th semester (spring)

Diploma Theses		Bakošová, Dvoran, Karšaiová, Mészáros, Mikleš, Seč, Zemanovičová

V.2 PhD Study

Topics in Control Theory	(2 h)	Mikleš
Intelligent Control Systems	(2 h)	Dvoran
Modelling and Simulation		
of Processes	(2 h)	Mészáros
Software and Hardware		
of Control Systems	(2 h)	Danko

V.3 Course contents

V.3.1 Lectures

Automatic control fundamentals (2h/week, 6th semester)

Basic principles of devices and methods for measurement of technological quantities. Devices for control of technological processes. Continuous-time, discrete and digital controllers. Servo-drives. Industrial controllers. 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 a closed loop. Stability of systems. Synthesis of controllers. Control of special types of processes of chemical technology.

Process Control (1h/week, 7th semester)

Introduction to process control. Mathematical models of linear and nonlinear continuous-time systems. 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. Responses of linear continuous-time systems: step, impulse and frequency responses, responses on arbitrary signals. Internal properties of linear continuous-time systems: stability, controllability, reachability, observability, properness, stabilisability. Feedback control loop. Basic types of controllers, quality of control, controller synthesis. Methods for controller synthesis. Mathematical models of linear discrete-time systems. Methods for discrete controller synthesis. Control of basic process units of chemical technology.

Process Dynamics (2h/week, 7th semester)

Basic approaches to process modelling. System classification according to accepted mathematical models. State-space and input-output models. Dynamic properties guessed from the models. Linearisation of nonlinear models. Nonlinear and linearised models of serially connected tanks, the static and dynamic properties. Dynamic properties of processes with heat exchange: tank heat exchangers with ideal mixing of media, tube heat exchangers, down-stream and upstream cases. Dynamic properties of processes with material exchange: plate distillation columns, stuffed distillation columns, stuffed absorption columns. Dynamic properties of processes with chemical reactions: continuous-time stirred tank reactors, tube reactors without or with catalyst.

Operating Systems (1h/week, 7th semester)

Types of computers, basic hardware of computers, basic components and their classification, periphery equipment. Introduction to operating systems of computers. Multitasking, types of multitasking and their comparison. MS Windows, its versions and their comparison from the operating system point of view, configuration of MS Windows. Linux – operation system of UNIX-type, its installation and types. UNIX operating system, its properties, structure, commands, shells, editors. WAN nets. INTERNET and SANET nets. Communication tools telnet, elm, talk, ftp, gopher, www (lynx, netscape). LAN nets, their types and comparison. NetWare 3.x, 4.x, properties and philosophy. TCP/IP protocol, its configuration

Control Devices and Systems (2h/week, 7th semester)

Continuous-time controllers, types and their static and dynamic behaviour. Discrete controllers, their dynamic behaviour and using in an closed-loop. PC in the role of a controller. Servo-drives for electric and pneumatic control system. Control valves. Digital devices. Logic functions, electric devices for realisation of logic functions. Sequence loops. Hardware for control of technological processes. Analog input modules, A/D, D/A converters. Digital input modules. Sources of inaccuracies in control loops.

Computer programs (1h/week, 7th semester)

Matlab programming language: internal properties, variables, functions, data analysis, data visualisation, 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 visualisation, special functions. Word - text processor.

Optimisation (2h/week, 8th 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, 8th 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 stabilising controllers. BIBO stability. Parameterisation of stabilising 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 generalised algebraic Riccati equations. Connection between LQG and H_2 control.

Experimental identification (2h/week, 8th 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 Polymerisation Processes (2h/week, 8th 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 fiber 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, 9th 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, 9th 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, 9th 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, 9th 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 visualisation. 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, 9th semester)

Introduction to process control. Mathematical models of basic process units of chemical technology. Principles of control of technological processes. Methods for controller synthesis, types of control loops. Control of heat exchangers, controlled and action variables, control loops. Control of distillation and absorption columns, controlled and action variables, control loops. Control of chemical reactors, controlled and action variables, control loops.

V.3.2 Laboratory exercises

Informatics (2h/week, 2nd semester)

MS Windows 95 operating system. MS Excel as a tool for data processing, data processing by tables, data visualisation by graphs. MS Word – text processor.

Computer based data processing (2h/week, 5th semester)

Matlab – Simulink as a tool for system simulation, Matlab – Control toolbox. Filtration of signals, analog and digital filters, Matlab – Signal processing toolbox. MS Excel as a tool for data processing. Data processing by tables, data visualisation by graphs, analytical tools in MS Excel, statistics in MS Excel. Origin as a tool for data visualisation and processing.

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

Measurement of technological quantities: pressure, flow-rate, level, temperature. Measurement of static characteristics and step responses of sensors and transmitters. Measurement of dynamic properties of a pneumatic PI controller. Simulation of step responses of a heat exchanger, a tank and two serially connected tanks.

Laboratory exercises of Control Theory I (2h/week, 8th semester)

Simulation of pole-placement method. State-space approach. State observer design for simple systems. Simulation of state feed-back. Simulation of feedback control with a state observer. Design of a set of stabilising controllers for simple systems. Simulation of MIMO feedback systems by using of stabilising 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, 8th semester)

Simulation of dynamic properties of systems in Matlab – Simulink. Stability conditions and responses of systems on standard input signals. Transformation of state-space description to transfer function and vice-versa, transformation of higher order differential equation to a system of the 1st order differential equations. Analysis of static and dynamic properties of a system of serially connected tanks with/without interactions. Analysis of static and dynamic properties of a tube heat exchanger as a system with continuously distributed parameters. Modelling of a system with continuously distributed parameters, transformation of a system of partial differential equations to a system of ordinary differential equations by discretisation. Calculation of a steady-state of a plate distillation column, analysis of static and dynamic properties of a plate distillation column as a system with discretely distributed parameters. Analysis of static and dynamic properties of an exothermic continuous-time stirred tank reactor. Calculation of steady-states of chemical reactors, steady-state analysis of chemical reactors, linearisation of nonlinear models.

Laboratory exercises of Control Theory II (2h/week, 9th 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, M. Karšaiová, A. Mészáros, J. Mikleš, 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 (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:

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 (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.

4. Adaptive Controllers (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:

a) self-tuning control - characterised by repeating parameter estimation and control design
b) model reference adaptive control based on the Lyapunov method
c) decentralised adaptive control

5. Neural Networks (A. Mészáros)

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, A. Zemanovičová)

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)

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 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.

8. 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 are studied.

9. Process Control

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

VI.2 Research Projects in Slovak Republic

1. Development of advanced control methods for chemical reactors, distillation columns and other plants in chemical and food technology (Ján Mikleš)

Most units of chemical technology are described by non-linear models. Non-linear models and techniques and robust approach to control design are nowadays urgently developed, verified and investigated. The main goals of the project can be formulated in the following items:

- To derive mathematical models of chemical and biochemical processes: an exothermic reactor for decomposition of H_2O_2, a tray distillation column and a stuffed distillation column for separation of binary mixtures, a warm-air drying chamber, a biochemical reactor.

- To develop methods and algorithms for system identification: closed-loop identification, identification based on artificial neural network, identification of physical system parameters from measured data.
- To investigate modern optimisation methods and algorithms especially for distillation columns and biochemical reactors, which are usually nonlinear high-order systems.
- To investigate robust stabilisation and robust feedback control of multivariable systems.
- To develop adaptive control methods and to create a program package of adaptive control algorithms for control of systems of the chemical and food technology.
- To include principles of artificial intelligence (expert systems, fuzzy control, neuro-fuzzy control, artificial neural networks) into control structures for chemical processes.
- To investigate the predictive control method and to create control algorithms based on the Youla-Kučera parameterisation for solving unconstrained or constrained control problems.
- To verify all theoretical results on laboratory models chemical processes.
- To transform theoretical and experimental results into industrial conditions and to demonstrate benefits and advantages of advanced process control in chemical and food industry.

The most important results of the project are following: open-loop and closed-loop formulation of the control law, which gives the control signal as a finite sequence of minimum length, design of CVP based optimal control of an industrial depropanizer column, solving of a two step pole placement control design problem, where the pole placement method is combined with Youla-Kučera parameterisation, application of the adaptive λ-tracking method for control of nonlinear chemical processes, application of closed-loop identification method for identification of a laboratory chemical reactor, design of a PI LQ controller using static feed-back.

2. Adaptive and Intelligent Control of Biochemical and Chemical Processes (Alojz 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.
- 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.
- Implementation of principles of fuzzy control, neuro-fuzzy control and decentralised control to control structures for biochemical and chemical processes.
- Accomplishment of computer based control system for a laboratory fermenter LF-3.
- Data acquisition and processing utilising software filters on the fermenter LF-3, estimation of state variables in the on the basis of neural network approach.
- 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.

Original results obtained in the frame of the project are: training of artificial
neural networks in the role of controllers using stochastic approximation method, adaptive neural PID controller, iterative dynamic programming method using artificial neural networks for solving unconstrained and constrained dynamic optimisation problems, where an artificial neural network is used as a predictor, predictive control algorithms based on artificial neural networks, where both a recurrent artificial neural network and a feedforward artificial neural network are used; determination of optimal feed rate profile in fed-batch fermenters, data-based system of equipment for global using.

VI.3 International Scientific Programmes

1. INCO COPERNICUS CP97:7010

The European Network for Industrial Application of Polynomial Design Methods – EUROPOLY

Coordinator at the FCT STU: J. Mikleš

Participants: Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic, Prague, Czech Republic; University of Twente, Twente, Netherlands; University of Glasgow, Glasgow, Great Britain; Uppsala University, Uppsala, Sweden; University of Strathclyde, Strathclyde, Great Britain; Politecnico di Milano, Milan, Italy; CNRS – LAAS, Toulouse, France; Czech University of Technology, Prague, Czech Republic; Technical University of Brno, Brno, Czech Republic; Department of Process Control, Faculty of Chemical Technology, Slovak University of Technology, Bratislava, Slovakia; Warsaw University of Technology, Warsaw, Poland; Swiss Federal Institute of Technology, Zurich, Switzerland; ProCS, Ltd., Šaľa, Slovakia; Compureg Plzeň, Plzeň, Czech Republic

Period: January 1998 – December 2000

2. Project of Austrian - Slovak Scientific Cooperation: Aktion Österreich – Slowakei No. 26s12

Optimisation of a Combustion Process from the Environmental Point of View

Coordinator at the FCT STU: A. Zemanovičová

Participants: Faculty of Chemical Technology, Slovak University of technology, Bratislava, Slovakia; Technical University of Vienna, Vienna, Austria

Period: April 1999 – December 2000

3. Project of Slovak – Czech Scientific CooperationNo. 112/344

Development of Advanced Control Methods for Processes of Chemical and Food Technology

Coordinator at the FCT STU: J. Mikleš

Participants: Department of Process Control, Faculty of Chemical Technology, Slovak University of Technology, Bratislava, Slovakia; Department of Process Control and Computer Techniques, University of Pardubice, Pardubice, Czech Republic

Period: January 2000 – December 2001

VII. COOPERATION

VII.1 Cooperation in Slovakia

Department of Automatic Control Systems, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Bratislava

Department of Automation and Control, 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

Institute of Control Theory and Robotics, Slovak Academy of Sciences, Bratislava

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

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

Slovnaft, Inc., Bratislava

NCHZ, Inc., Nováky

ProCS, Ltd., Šaľa

Fuzzy, Ltd., Diakovce

VII.2 International Cooperation

Department of Process Control and Computer Techniques, 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

Department of Automatic Control, Faculty of Technology Zlín, Technical University Brno, 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
- Predictive control

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

- Dynamic optimisation and control of distillation columns

Ecole Nationale Superieure des Ingénieurs de Génie Chimique-Chemin de la Loge, Toulouse, France

- Neural networks
- Predictive control

University of Bochum, Bochum, Germany

- Closed-loop identification
- Predictive control

University of Dortmund, Dortmund, Germany

- 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 Organisations and Societies

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

Slovak Society of Chemical Engineering, Bratislava (M. Bakošová, J. Danko, J. Dvoran, M. Fikar, M. Karšaiová, J. Maťko, A. Mészáros, J. Mikleš, M. Ondrovičová, A. Zemanovičová)

Slovak Union of Industrial Chemistry, Science- technical Society, Bratislava (M. Bakošová, J. Danko, J. Dvoran, M. Fikar, M. Karšaiová, D. Lázničková, J. Maťko, A. Mészáros, J. Mikleš, M. Ondrovičová, A, Seč, A. Vasičkaninová, A. Zemanovičová, Ľ. Čirka, J. Dzivák, F. Jelenčiak, Š. Kožka, A. Rusnák)

VII.4 Membership in International Organisations and Societies

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

European Federation of Biotechnology, Brussels, Belgium (A. Mészáros)

The New York Academy of Sciences, New York, USA (A. Mészáros)

VIII. THESES AND DISSERTATIONS

VIII.1 Graduate Theses (MS Degree) for state examinations after five years of study (supervisors are written in brackets)

Benyová E.: Optimisation and control of a chemical reactor. (M. Karšaiová)

Debnárová L.:	Control of a plate distillation column for separation of a binary mixture methanol – water. (M. Bakošová)
Domonji M.:	Control design for liquid tanks. (M. Karšaiová)
Hudáček P.:	Design of a neuro-fuzzy control system. (J. Dvoran)
Huseríková M.:	Computer control of a laboratory model of liquid tanks. (A. Mészáros)
Kvasnica M.:	Optimal feed-back control of a laboratory chemical reactor with an exothermic reaction. (J. Mikleš)
Mikulíková J.:	Adaptive λ-tracking of nonlinear chemical processes. (M. Bakošová)
Nemec J.:	Control of a real process with time-delay. (A. Zemanovičová)
Szanyiová A.:	Adaptive control of a biochemical process. (A. Mészáros)
Veliký O.:	Control design for a mathematical and real model of a stuffed distillation column. (A. Seč)
Ziman Ľ.:	Identification of a chemical reactor with an exothermic reaction. (J. Mikleš)

IX. PUBLICATIONS

IX.1 Journals (registered in Current Contents)*

[1] Bakošová M., Ondrovičová M., Karšaiová M.: Riadenie rektifikačných kolón metódou adaptívneho λ-sledovania. Control of distillation columns via adaptive λ-tracking method (in Slovak). AT&P Journal 7 (4), 76 – 77 (2000).

[2]* Danko J., Ondrovičová M.: Adaptive control of a laboratory tank reactor. Chem. Papers 54 (3), 155 – 158 (2000).

[3]* Fikar M., Kučera V.: On minimum finite length control problem. Int. J. Control 73 (2), 152 – 158 (2000).

[4]* Fikar M., Latifi M. A., Corriou J. P., Creff Y.: CVP-based optimal control of an industrial depropanizer column. Computers and Chemical Engineering 24, 909 – 915 (2000).

[5] Fikar M., Unbehauen H.: Two step pole placement control design. Journal of Electrical Engineering 51 (9 – 10), 235 – 239 (2000).

[6] Fikar M.: Použitie lineárnych maticových nerovností v riadení. Using of linear matrix inequalities in control (in Slovak). AT&P Journal 7 (4), 78 – 79 (2000).

[7] Fikar M.: Prediktívne riadenie s nominálnym regulátorom. Predictive control with a nominal controller (in Slovak). AT&P Journal 7 (11), 49 – 51 (2000).

[8] Kožka Š., Mikleš J.: Identifikácia laboratórneho chemického reaktora v uzavretom regulačnom obvode. Closed-loop identification of a chemical reactor (in Slovak). AT&P Journal 7 (10), 52 – 53 (2000).
[9] Mészáros A., Andrášik A., Rusnák A.: Vlastnosti adaptívneho neurónového PID regulátora. Properties of an adaptive neural PID controller (in Slovak). AT&P Journal 7 (4), 69 – 71 (2000).
[10] Mészáros A.: Matematické modelovanie rúrkového chemického reaktora pre účely simulácie a riadenia. Mathematical modelling of a tubular chemical reactor for simulation and control purposes (in Slovak). AT&P Journal 7 (10), 59 – 63 (2000).
[11] Mészáros A.: Modelovanie biochemických reaktorov. Modelling of biochemical reactors (in Slovak). AT&P Journal 7 (9), 66 – 69 (2000).
[12] Mikleš J., Čirka Ľ., Kvasnica M.: Návrh PI LQ regulátora pomocou statickej spätnej väzby. Design of a PI LQ controller via static feed-back (in Slovak). AT&P Journal 7 (10), 54 – 55 (2000).
[13] Mikleš J., Dzivák J., Jelenčiak F., Kožka Š., Fikar M., Mészáros A.: Polynomial design methods applied to feedback control of a continuous stirred tank reactor. EUROPOLY Newsletter (1), 8 – 10 (2000).

*IX.2 Conferences (*International conferences)*

[1]* Andrášik A., Rusnák A., Mészáros A.: Dynamic performance of adaptive neural PID control. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP203 (2000).
[2]* Bakošová M., Karšaiová M., Ondrovičová M., Danko J.: Adaptive λ-tracking for nonlinear chemical processes. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP112 (2000).
[3]* Bakošová M., Karšaiová M., Ondrovičová M.: Application of high-gain adaptive λ-tracking for nonlinear chemical processes. In: CD ROM of full texts of the 14th International Congress of Chemical and Process Engineering CHISA 2000. Praha, Czech Republic, Aug. 27.- 31. 2000, CD ROM 0099 (2000).
[4]* Bakošová M., Mészáros A., Ondrovičová M., Karšaiová M.: Control of distillation columns via adaptive λ-tracking method. In: CD ROM of full texts of the 27th International Conference of SSCHI. Tatranské Matliare, Slovak Republic, May 22. – 26. 2000, CD ROM P201 (2000).
[5]* Čirka Ľ., Fikar M.: IDTOOL – A dynamical system identification toolbox for Matlab. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP149.2 (2000).
[6]* Danko J., Ondrovičová M. : Computer control of a drying chamber. In: Proceedings of the 4th Scientific - Technical Conference Process Control

2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP151 (2000).
[7]* Dzivák J., Mikleš J., Jelenčiak F., Kožka Š.: Control of a stirred tank reactor. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP156 (2000).
[8]* Fikar M., Unbehauen H., Mikleš J.: Polynomial approach to stable predictive control. In: Preprints of the 3rd IFAC Symposium on Robust Control Design. Prague, Czech Republic, June 21. – 23. 2000, CD ROM EUR-07 (2000) .
[9]* Fikar M., Unbehauen H.: Polynomial approach to constrained receding horizon predictive control. In: Preprints of the IFAC Conference Control System Design. Bratislava, Slovak Republic, June 18. – 20. 2000, p. 247 – 252 (2000).
[10]* Jelenčiak F., Mikleš J., Dzivák J., Dvoran J.: Stability analysis of a chemical reactor using Ljapunov indirect method. In: Proceedings of International Carpathian Control Conference. High Tatras – Podbanské, Slovak Republic, May 23. – 26. 2000, p. 431 – 434 (2000).
[11]* Jelenčiak F., Mikleš J., Dzivák J., Kožka Š.: Ljapunov stability analysis of a chemical reactor. In: CD ROM of full texts of the 27th International Conference of SSCHI. Tatranské Matliare, Slovak Republic, May 22. – 26. 2000, CD ROM P335 (2000).
[12]* Jelenčiak F., Mikleš J., Dzivák J., Kožka Š.: Stability analysis of a chemical reactor using Ljapunov indirect method. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000 Czech Republic, CD ROM RIP157 (2000).
[13]* Karšaiová M., Bakošová M., Ondrovičová M., Mészáros A : Design of control method for distillation columns. In: CD ROM of full texts of the 27th International Conference of SSCHI. Tatranské Matliare, Slovak Republic, May 22. – 26. 2000, CD ROM P119 (2000).
[14]* Karšaiová M., Bakošová M., Ondrovičová M.: Decentralized control of nonlinear chemical processes. In: CD ROM of full texts of the 14th International Congress of Chemical and Process Engineering CHISA 2000. Praha, Czech Republic, Aug. 27.- 31. 2000, CD ROM 1025 (2000).
[15]* Karšaiová M., Danko J., Bakošová M., Ondrovičová M.: Control design of real object. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP153 (2000).
[16]* Kožka Š., Mikleš J., Fikar M., Jelenčiak F., Dzivák J.: Closed-loop identification of a laboratory chemical reactor. In: Preprints of the 3rd IFAC Symposium on Robust Control Design. Prague, Czech Republic, June 21. – 23. 2000, CD ROM EUR-03 (2000).

[17]* Kožka Š., Mikleš J., Jelenčiak F., Dzivák J.: Identification of laboratory chemical reactor in closed-loop via Youla-Kučera parameterisarion. In: Proceedings of the 3rd IMACS Symposium on Mathematical Modelling. Vienna, Austria, Feb 2. – 4. 2000, vol.2, p. 705 – 708 (2000).
[18]* Lázničková D., Dvoran J. : Control of through-flow reactor. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP149.1 (2000).
[19]* Mészáros A , Szányiová J., Andrášik A.: MRAS based control of a fermentation process. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP202.1 (2000).
[20]* Mészáros A., Andrášik A., Rusnák A.: Application of artificial neural network strategies in process control. In: Preprints of the Euro-International Symposium on Computational Intelligence. Košice, Slovak Republic, Aug. 30. – Sept. 1. 2000, p. 268 – 275 (2000).
[21]* Mészáros A., Andrášik A., Szányiová J.: Počítačové riadenie laboratórneho fermentora. Computer control of a laboratory fermenter. In: CD ROM of full texts of the 27th International Conference of SSCHI. Tatranské Matliare, Slovak Republic, May 22. – 26. 2000, CD ROM P204 (2000).
[22]* Mikleš J., Čirka Ľ., Kvasnica M.: Design of a controller by static output feedback. In: Proceedings of International Carpathian Control Conference. High Tatras – Podbanské, Slovak Republic, May 23. – 26. 2000, p. 459 – 462 (2000).
[23]* Mikleš J., Kožka Š., Čirka Ľ.: PID controller and LQ control design. In: Preprints of the IFAC Workshop on Digital Control. Past, present and future of PID Control. Terrassa, Spain, April 5. – 7. 2000, p. 315 – 319 (2000).
[24]* Ondrovičová M., Bakošová M., Karšaiová M., Jelenčiak F. : Identification and control of a laboratory distillation column. In: CD ROM of full texts of the 27th International Conference of SSCHI. Tatranské Matliare, Slovak Republic, May 22. – 26. 2000, CD ROM P118 (2000).
[25]* Ondrovičová M., Bakošová M., Karšaiová M.: Laboratory distillation column control with closed-loop identification. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP152 (2000).
[26]* Prokop R., Bakošová M., Prokopová Z.: PID control of unstable time-delay systems: tuning and robustness. In: Preprints of the IFAC Conference Control System Design. Bratislava, Slovak Republic, June 18. – 20. 2000, p. 420 – 425 (2000).
[27]* Rusnák A., Mészáros A., Andrášik A.: Control system for a laboratory fermenter. In: Proceedings of the 4th Scientific - Technical Conference

Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP202.2 (2000).
[28]* Seč A., Čirka Ľ.: Batch filled distillation column. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP222 (2000).
[29]* Vasičkaninová A., Zemanovičová A. : Fuzzy controller design for concentration system. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP154 (2000).
[30]* Vasičkaninová A., Zemanovičová A.: Neuro-fuzzy controller design for concentration systems. In: Proceedings of International Carpathian Control Conference. High Tatras – Podbanské, Slovak Republic, May 23. – 26. 2000, p. 527 – 530 (2000).
[31]* Zemanovičová A., Vasičkaninová A., Hofbauer H.: Control of time-delay systems. In: Proceedings of the 4th Scientific - Technical Conference Process Control 2000. Kouty nad Desnou, Czech Republic, June 11.-14. 2000, CD ROM RIP155 (2000).

IX.3 Books and Textbooks

[1] Mikleš J., Fikar M.: Process modelling, identification and control I. Models and dynamic characteristics of continuous processes. STU Press, Bratislava. 170 s., (2000).