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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(missing: M. Kalúz, J. Dvoran)

CONTENTS

I PREFACE

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

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

Teaching and research activities of the department are oriented on process control, identification and modelling of systems, adaptive control, construction and testing of measuring devices and equipment, and on development of software packages for intelligent control systems. Second branch is devoted to information technologies, data management, and Internet programming.

prof. Ing. Miroslav Fikar, DrSc.

II INTRODUCTION

This report summarizes the teaching and research activities at the Department of Information Engineering and Process Control at the Faculty of Chemical and Food Technology at the Slovak University of Technology in Bratislava during the period 1 January – 31 December 2012.

Department of Information Engineering and Process Control of the FCFT STU in Bratislava was constituted from the Department of Measuring and Control Technique of the Faculty of Electrical Engineering of the Slovak University of Technology in Bratislava in 1962. Because of the specific control problems of the processes and systems in the chemical and biochemical technologies, the specialization Process Control in the frame of the study branch Chemical Engineering and Process Control has been established. Students and postgraduate students have been educated since 1964. So far, more than four hundreds specialists and almost thirty PhD students have been graduated here and three professors and nine associated professors have been appointed. Since 2005, Department of Information Engineering and Process Control and Department of Mathematics have formed Institute of Information Engineering, Automation, and Mathematics.

The first head of the department was Prof. Daniel Chmúrny, DrSc in 1962 – 1986. Prof. Ján Mikleš, DrSc headed the department in 1986 – 1994 and in 1998 – 2003. The head in 1995 – 1997 was Assoc. prof. Alojz Mészáros, PhD and prof. Ing. Miroslav Fikar, DrSc. has headed the department since 2003.

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

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IV TEACHING AND RESEARCH LABORATORIES

Laboratory of Process Control:	Distillation Column UOP3CC, Multifunction station Armfield PCT40, Liquid Tanks DTS200, Training Station Armfield PCT23
Laboratory of Control Systems:	MATLAB/Simulink, Siemens-SIMATIC S-7 200, Lego Mindstorms NXT 2.0, Thermo-optical System uDAQ28/LT, Ball & Plate CE 151, Magnetic Levitation
Laboratory of industrial technology:	Siemens-SIMATIC S-7 300, FOXBORO, MATLAB/Simulink, B&R, VIPA 300S, eWONx005CD, dSPACE
Computer Laboratory:	Solaris

V. EDUCATIONAL ACTIVITIES

V.1 Bachelor Study

1st semester (autumn)

Computer Based Data Processing	0/0/2	Drgoňa, Jelemenský, Karšaiová, Takács, Kmeťová

2nd semester (spring)

Informatisation and Information Systems	1/2/0	Blažek, Čirka, Kalúz, Szücs
Operating Systems	1/2/0	Fikar, Valo

3th semester (autumn)

Modelling	2/0/3	Oravec, Vasičkaninová, Závacká

4th semester (spring)

Laboratory Exercises of Process Control	0/0/2	Karšaiová, Oravec, Vasičkaninová
Process Control	2/0/0	Bakošová
Optimisation	2/3/0	Dvoran, Števek

5th semester (autumn)

Design of Information and Control Systems	2/3/0	Kvasnica, Valo

6th semester (spring)

Process Control	2/0/0	Bakošová
Laboratory Exercises of Process Control	0/0/2	Karšaiová, Oravec, Števek, Vasičkaninová, Závacká
Integrated Control in Process Engineering	2/0/3	Bakošová, Karšaiová, Vasičkaninová
Computer Based Data Processing	0/0/2	Oravec

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

V.2 Master Study

1st semester (autumn)

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

2nd semester (spring)

Technological Process Control	1/1/0	Dvoran
Identification	2/0/2	Čirka, Fikar
Industrial Control and Information Systems I	2/0/1	Kvasnica, Valo
Automatic Control Theory II	3/0/2	Čirka, Fikar

Semestral Project II	0/0/3	Bakošová, Čirka, Fikar, Karšaiová, Kvasnica, Valo, Vasičkaninová

3rd semester (autumn)

Automatic Control Theory III	3/0/2	Fikar, Závacká
Information Technologies II	1/1/0	Čirka
Industrial Control and Information Systems II	2/0/2	Holaza, Kvasnica
Optimization of Processing and Production	2/0/2	Dvoran
Diploma Project	0/0/4	Bakošová, Čirka, Kalúz, Kvasnica, Valo, Vasičkaninová

4th semester (spring)

Model Predictive Control	2/0/1	Kvasnica, Szücs
Intelligent Control	2/0/1	Dvoran
Robust Control	2/0/1	Bakošová
Diploma Thesis	0/0/17	Bakošová, Čirka, Fikar, Kvasnica, Valo, Vasičkaninová

V.3 PhD Study

1st semester (autumn)

Automatic Control Theory (Selected topics)	4/0/0	Mikleš

3rd semester (autumn)

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

V.4 Course contents

V.4.1 Lectures in Bachelor study

Optimisation (2h/week, 4th semester)

Static optimisation, classification of problems, goal functions, boundaries. Extremum without boundaries – analytical methods. Single-dimensional case, multi-dimensional case, Hess matrix. Conditions for extremum. Extremum with boundaries – linear boundaries, direct method, method of Lagrange multipliers. Extremum with boundaries – nonlinear boundaries, Kuhn – Tucker theorem. Non-gradient methods – Box-Wilson method, flexible simplex method, method of cyclic exchange of parameters. Gradient methods – Regula falsi method, Newton method, Broyde method, DFP method, PARTAN method. Convergence of gradient methods.

Modelling (2h/week, 3rd semester)

Fundamentals of chemical process modelling and simulation. Linear and nonlinear state-space models. Mathematical models of selected chemical processes with lumped parameters. Nonlinear and linearized models of a tank and serially connected tanks. Linear and nonlinear models of mixing processes. Mathematical models of processes with heat transfer: recuperative heat exchanger, shell heat exchanger, flow heater. Nonliner and linearized mathematical models of continuous stirred tank reactors. Dynamic and static behaviour of processes.

Operating Systems (1h/week, 2nd semester)

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

Process Control (2h/week, 4th and 6th semester)

Introduction to process control. Modelling of special types of processes of chemical technology. Static and dynamic behaviour of controlled systems. Closed loop for control of technological processes. Controllers. Dynamic behaviour of closed loops. Stability of systems. Synthesis of controllers. Control of special types of processes of chemical technology. Basic principles of devices and methods for measurement of technological quantities.

Design of Information and Control Systems (2h/week, 5th semester)

Basic principles and methods for control systems design concerning control aims requirements. Systematic design approach. Utilization of modern software and technical tools for control design. Information control supply.

Integrated Control in Process Engineering (2h/week, 6th semester)

Feedback and feed-forward control. More complex control structures: cascade control, feed-forward-feedback control, control loop with auxiliary control input, time-delay compensator – Smith predictor, flow-ratio control, special cases of multivariable control. Process control: control of storage tanks, control of mixing units, control of heat exchangers, control of distillation columns, control of chemical reactors, control of dryers.

Information and Information Systems (1h/week, 2st and 6th semester)

Information system, systems for data processing. Database system structure. Logic data organization methods, database architecture. Means of data defining and manipulation. SQL language. Visualisation level of technological and production process control. SCADA/HMI (Supervising Control and Data Acquisition / Human Machine Interface) application design. Professional software packages and components (WinCC, dSPACE/Control Desk, MATLAB/MWS for Windows XP/2000/NT). Creating HTML application and dynamic web pages bounded to control system databases, SCADA/HMI systems etc.

V.4.2 Lectures in Master study

Programming of Network Application (1h/week, 1st semester)

PHP language a SQL database systems basics. Internet programming. Process or other database sources data and measurement processing.

Technical Means of Automation (2h/week, 1st semester)

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

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

Introduction to modeling in process engineering, modeling of processes with discretely and continuously distributed parameters: tubular heat exchangers, tray distillation columns, packed distillation columns, packed absorption columns; modeling of extractors without and with chemical reactions; modeling of tubular chemical reactors without and with catalyst; modeling of batch and semi-batch processes: chemical reactors, extractors and distillation columns.

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

State-space process models. Stability, controllability, observability of continuous-time systems. Input-output process models. BIBO stability. Lyapunov stability. Matrix fraction descriptions.

Frequency analysis. Bode plot. Nyquist plot. Nyquist stability criterion. Gain and phase margins. Closed-loop frequency responses.

State-space discrete-time models. Input-output discrete-time models. Controllability and observability of discrete-time systems. Direct digital control. Stability of discrete-time systems. Discrete-time feedback systems.

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

Introduction to control of technological processes. Principles of control of technological processes: feedback and feed-forward control. Simple feedback control loop. Methods for PID controller tuning. Complex control loops: time-delay compensation (Smith predictor), cascade control, feed-forward compensation of disturbances, flow-ratio control. Control of tanks, control and controlled variables. Control of heat exchangers, controlled and control variables, control loops. Control of distillation and absorption columns, controlled and control variables, control loops. Control of chemical reactors, controlled and control variables, control loops. Basic principles of devices and methods for measurement of technological quantities: liquid level, temperature, pressure, flow rate, concentration.

Information Technologies I (1h/week, 1st semester)

Computer terminology. Basic hardware and software. Network protocols and architectures. Data security and protection. Design of static web pages. Basic structure of a web page. XHTML language – elementary tags and attributes. Cascade style sheet formatting.

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

Basic principles and stages of industrial information system design. System reliability and diagnostics. Projecting and control design of selected

technologies using an appropriate software. PLC systems and Profibus. WinCC visualisation tools. Programming with use of ladder logic, state list, and function block diagrams.

Identification (2h/week, 2nd semester)

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

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

Optimal control and principle of minimum. LQ control. Dynamic programming. Observers and state estimation. Kalman filter. State feedback with observer. Diophantine equations. Polynomial pole placement control design. Youla parametrisation. Parametrisation of stabilizing controllers. Parametrised controller in the state-space. Observer-based controller, state-space and polynomial interpretations. LQ control design for MIMO systems. LQG control, state-space and polynomial interpretation. H2 control, state-space and polynomial interpretation. Model uncertainty and robustness. Small gain theorem. Linear fractional transformation. Riccati equations. HINF control, state-space and polynomial interpretation, Robust stabilization of coprime factors. Loop shaping.

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

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

Automatic Control Theory III (3h/week, 3rd semester)

Adaptive Control: self-tuning and MRAC. Advanced process control: heat exchangers, distillation columns, waste-water treatment plants, crystallisation, centrifuges, neutralisation, ORP. MIMO control: RGA, decoupling.

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

The aim of this course is to teach students to work with industry information systems. The principles and means of communication in the design of information and communication systems: XML, DTD, XML Schema, Xpath, XSLT, SVG.

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

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

Model Predictive Control (2h/week, 4th semester)

Introduction to principles of the predictive control, types of models and objective functions. Formulation of a problem as the optimisation problem with aim to predictive control of the chemical technology systems.

Introduction to predictive control and definition of the main terms. Explanation of the norms and their application in LP and QP problems. Construction of the optimisation problems and their implementation in YALMIP. State-tracking, output tracking, predictive control with integrator and time-varying reference tracking. Explicit model predictive control.

Robust Control (2h/week, 4th semester)

Introduction to the robust control and one-parametric uncertainties. Interval uncertainties, robust stability analysis of systems with interval uncertainties and Kharitonov Theorem. Synthesis of robust controllers for systems with interval uncertainties. Polytopic uncertainties, edges, analysis of robust stability for the polytopic systems and Edge Theorem. Multi-linear parametric uncertainties. Design of robust control for the systems with parametric uncertainties, simultaneous stabilization. Low gain theory, generalized Kharitonov Theorem.

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

Intelligent Control (2h/week, 4th semester)

Introduction to the artificial intelligence, recognition methods (attribute and structural). Problem solving, expert systems (diagnostic and planning). Fuzzy logic, fuzzy identification, modelling and control. Neural networks in

identification and control. Neuro-fuzzy control and genetic algorithms in intelligent control.

V.4.3 Laboratory exercises in Bachelor study

Computer Based Data Processing (2h/week, 1st and 3rd semester)

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

Optimisation (3h/week, 4th semester)

Extremum without boundaries – analytical methods. Single-dimensional case, multi-dimensional case. Extremum with boundaries – linear boundaries, direct method, method of Lagrange multipliers. Extremum with boundaries – nonlinear boundaries. Non-gradient methods – Box-Wilson method, flexible simplex method, method of cyclic exchange of parameters. Gradient methods – Regula falsi method, Newton method, Broyde method, DFP method, PARTAN method.

Laboratory Exercises of Process Control (2h/week, 4th and 6th semester)

MATLAB/Simulink as a simulation tool for LEPC. Laplace transform as a mathematical tool for LEPC. Input-output description of dynamic systems, transfer functions, poles and zeros. Step responses and impulse responses of dynamic systems. Mathematical models and dynamic behaviour of processes of chemical technology. Feedback control. PID controllers and their properties in feedback control. Controller synthesis and control of processes of chemical technology.

Laboratory Exercises of Information Engineering and Systems (1h/week, 6th semester)

Introduction to information systems and technologies. Electronic computers, computer software and computer networks. Internet. Language XHTML a CSS. Installation and setting of the software for programming (Apache, PHP,
MySQL). Principles of programming language PHP. Work with databases.

VI. CURRENT RESEARCH ACTIVITIES

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

VI.1 Main Research Areas

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

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

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

System identification deals with problem of the parameter estimation of static or dynamic systems from observed input-output data. Among many topics of system identification, the following areas have been investigated in this project:

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

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

Optimal Control Design (M. Fikar, J. Mikleš)

The main aim of this area is to develop a package of algorithms and program implementation of various known control design for a given plant. The research interests include single input-single output systems as well as multivariable dynamic systems. Control design covers strategies in discrete-time and continuous-time formulation. A program package is created in MATLAB and Simulink environment.

Adaptive Control (M. Bakošová, Ľ. Čirka, M. Fikar, A. Mészáros, J. Mikleš)

Most of technological plants exhibit non-linear behaviour. To apply a successful control design to practical problems is a substantial effort. The processes are known to be modelled and controlled with serious difficulties caused by their non-linear behaviour, high order dynamics, and tendency to instability. Many of industrial processes must be considered as multivariable systems. In a great deal of available control design techniques it is often necessary to carry out the steps of modelling, identification and control design. Theory and implementation of adaptive control in technological systems have been the long-time research topics. The activities in the adaptive control have been concentrated to three main areas as follows:

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

Neural Networks and Fuzzy Control (A. Mészáros, J. Dvoran, A. Vasičkaninová)

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

Model Predictive Control (M. Fikar, M. Kvasnica)

Model Predictive control (MPC) has been successful not only in academia but in industrial process applications as well. Its main drawbacks are the stability problems. The aim of this research is to enhance the basic input-output predictive methods. The problem is solved by means of the Youla-Kučera parametrisation of all stabilising controllers. Both finite and infinite horizon formulations are handled. Another approach is to assume that the loop is already controlled by a linear controller and to find the minimum number of control, or tracking error steps that leads to stable closed-loop behaviour. In all cases, it can be shown that the minimum number of steps is closely related to the number of unstable poles/zeros of the plant. Another area of research is development of new methods for explicit model predictive control. In this

approach, the optimal solution to the given MPC problem is obtained for all admissible initial conditions by employing parametric programming methods. The resulting optimal feedback law is then represented by a look-up table, which allows for real-time implementation of MPC to processes with rapid sampling.

Dynamic Optimisation (M. Fikar)

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

Modelling and Control of Chemical Reactors, Biochemical Reactors, Distillation Columns and Heat Exchangers (M. Bakošová, J. Dvoran, Ľ. Čirka, M. Fikar, M. Karšaiová, A. Mészáros, J. Mikleš, A. Vasičkaninová)

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

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

Research in this domain focuses on application of information technologies in control education. This covers interactive on-line blocks and automatic generation of testing problems. The current research involves personification of students problems.

Information Technologies (M. Fikar, Ľ. Čirka, M. Kvasnica)

Research in this domain is oriented to:

- application of information technologies for data treatment and visualisation
- development of static and dynamic web pages not only for purposes of measurement and control but for general information treatment
- automatic data acquisition from various internet sources

Open Source solutions are applied: web, mail, smb servers, databases (MySQL), programming tools (PHP, JavaScript) on operating systems GNU/Linux, FreeBSD, Solaris.

VI.2 Research Projects in Slovak Republic

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

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

Period: 2011-2014

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

The scientific project deals with development of advanced control methods for systems with uncertainties and focuses on processes typical in chemical and food technologies, as e.g. chemical reactors, biochemical reactors, distillation columns, heat exchangers and other energy consuming processes. Development of methods of robust stabilization and robust predictive control of systems with uncertainties constitutes the core of the project and the goal is to assure more efficient energy saving control in comparison to classical approaches. Computational requirements and practical use will be taken into account in the design of control algorithms. Designed algorithms, controllers, and control structures will be tested by simulations and in laboratory conditions. They will be compared with classical ones from the viewpoint of energy consumption during the control.

Period: 2012-2015

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

The project is focused on research and development of optimal control methods of nonlinear systems. Such systems are typical in chemical and biochemical technologies as separations, chemical reactors, waste-water treatment plants. The project will deal with design of advanced methods and control algorithms that will be more effective than the actual ones with respect to memory consumption and computational power. This will make possible to implement easier newly developed methods in industrial control systems. On the top layer, dynamic optimization will be used for qualitative analysis and as a generator of optimal trajectories. The suboptimal bottom layer represented by MPC and robust controllers will approximate the desired optimal operation and we will study the degree of suboptimality of these approaches. Other goals include providing a user-friendly software implementation of such a two-tiered architecture accessible to typical control engineers, as well as validation of the proposed solutions on experimental devices.

Period: 2012-2015

4. Internal STU Grant: Universal Explicit Model Predictive Controllers (M. Kvasnica)

The project aims at developing novel techniques for designing well-performing controllers which could be implemented on a cheap hardware. Using Model Predictive Control (MPC) and parametric programming, one can synthesize so-called explicit MPC controllers in form of a look-up table. Although such controllers provide very fast implentation, they suffer from the fact that if the prediction model changes, the whole look-up table needs to be re-computed, which is time-consuming. Therefore in this project we aim at synthesizing so-called universal explicit MPC controllers which can be adapted to changing parameters of the prediction model on-the-fly. This task will be achieved by transforming the prediction model into the Brunovsky canonical form, in which the state update is a bilinear function of the states and the time-varying model parameters. The universal controllers will subsequently be obtained by either replacing the bilinear term by auxiliary variables, or by approximating the bilinearity by a piecewise affine function.

Period: 2011-2012

VI.3 Other Projects in Slovak Republic

1. 027/2009/4.1/OPVaV*:* Support for Finalisation of Centre of Excellence for Smart Technologies, Systems, and Services II

Partners:

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

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

Period: 1.1.2010-31.1.2013

2. OPVaV-2008/4.2/01-SORO*:* Development of a software prototype for online learning in public policy, support for dissemination of results in applied research

Partners:

- Slovak University of Technology in Bratislava: FCHPT STU in Bratislava (Prof. Fikar, Ing. Čirka, Ing. Vasičkaninová)
- Comenius University in Bratislava: FSEV UK

Research in software solutions for learning in public policy. Development of a software prototype and its technical documentation, pilot testing of the prototype. Support for implementation of the software prototype in public and private sectors

Period: 1.9.2009-1.2.2012

VI.4 International Scientific Programs

1. SK-FR-0004-11: Fr-Sk Cooperation Štefánik

Dynamic and Global Optimisation of Processes

Partners:

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

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

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

Period: 2012-2013

VII. COOPERATION

VII.1 Cooperation in Slovakia

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

- Institute of Automation, Measurement, and Applied Informatics, Faculty of Mechanical Engineering, Slovak University of Technology, Bratislava

- Institute of Informatics, Slovak Academy of Sciences, Bratislava

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

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

- Slovnaft, Inc., Bratislava

- NCHZ, Inc., Nováky

- Fuzzy, Ltd., Diakovce

- ProCS, Ltd., Šaľa

VII.2 International Cooperation

- Department of Process Control and Computer Techniques, Faculty of Chemical Technology, University of Pardubice, Pardubice, Czech Republic
(Control system design)

- Department of Computing and Control Engineering, Prague Institute of Chemical Technology, Prague, Czech Republic
(Control system design)

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

(Adaptive control, Robust control)

- Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic, Prague, Czech Republic
(Polynomial synthesis, Model Predictive Control)

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

- LSGP-CNRS, Ecole Nationale Superieure des Industries Chimiques (ENSIC), Nancy, France
(Dynamic optimisation and control)

- Ecole Nationale Superieure des Ingenieurs de Genie Chimique-Chemin de la Loge (ENSIGC), Toulouse, France
(Neural networks, Learning automata, Model Predictive Control)

- Automatic Control Laboratory, ETH Zurich, Switzerland
(Model Predictive Control, Modeling, analysis, and control of hybrid systems)

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

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

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

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

VII.3 Membership in Domestic Organizations and Societies

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

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

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

VII.4 Membership in International Organizations and Societies

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

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

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

- European Union Control Association (M. Fikar)

VIII. THESES AND DISSERTATIONS

VIII.1 Graduate Theses (Bc Degree)

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

J. Andoková — Modeling and Optimization of the Liquid Distribution Network Systems
(M. Kvasnica)

M. Franc — Web module for processing and analysis of data in the information system ÚIAM
(Ľ. Čirka)

K. Ľubušký — Simple controllers implementation on PLC
(M. Kvasnica)

M. Štefánik — Using of PID Controller for Control of Tanks for Liquid Storage
(M. Bakošová)

E . Szabová — Design of Quizzes for the Course Modelling in LMS Moodle
(M. Bakošová)

P . Virguľa — Optimal process control
(M. Fikar)

VIII.2 Graduate Theses (MS Degree)

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

M. Cmarík — Modeling and process control with using UniSim Design
(J. Závacká)

J. Drgoňa — Efficient Modeling of Hybrid Systems
(M. Kvasnica)

M. Dupejová — Use of aggregation methods for proposal technological process control
(M. Karšaiová)

J. Holaza	Complexity Reduction of Explicit Model Predictive Control (M. Kvasnica)
M. Jelemensky	Dynamic optimization of processes (M. Fikar)
L. Petáková	Dynamic optimization of processes (M. Fikar)
M. Polačková	Ability Analysis of Design Robust Controller (M. Karšaiová)
J. Rusnak	Graphical user interface for solving of global optimization problems (M. Fikar)
K. Sohajda	Robust model predictive control of heat exchangers (M. Bakošová)
A. Szakálová	Global optimization using alphaBB method (M. Fikar)
B. Takács	Geometric Approach to Approximation of Explicit MPC (M. Kvasnica)

IX. PUBLICATIONS

IX.1 Books

1 Fikar,M. – Malíková, Ľ. – Staroňová, K. – Vávrová, Ľ. – Beblavá, E. – Čirk a, Ľ. – Bajúszová, Z. – Halák, P. – Hanout, Z.: Research of needs and possibilities of online learning in public policy of middle Europe context and handbook for Moodle 2 lectors (in Slovak), FSEV UK v Bratislave, 2012.

IX.2 Chapter or pages in book

1 Blažek, S. – Kvasnica, M. – Fikar, M.: Java-based Platform for Testing and Validation of Explicit Model Predictive Control, In Selected Topics in Modelling and Control, Editor(s): Mikleš, J., Veselý, V., Slovak University of Technology Press, no. 8, pp. 110–114, 2012.

2 Holaza, J. – Takács, B. – Kvasnica, M.: Complexity Reduction in Explicit MPC via Bounded PWA Approximations of the Cost Function, In Selected Topics in Modelling and Control, Editor(s): Mikleš, J., Veselý, V., Slovak University of Technology Press, no. 8, pp. 27–32, 2012.

3 Jelemenský, M. – Petáková, L. – Paulen, R. – Fikar, M.: Dynamic optimization of emulsion polymerization reactor, In Selected Topics in Modelling and Control, Editor(s): Mikleš, J., Veselý, V., Slovak University of Technology Press, no. 8, pp. 1–6, 2012.

4 Karšaiová, M. – Polačková, M. – Bakošová, M. – Vasičkaninová, A.: Rob ust Control and Robust Performance of Technological Processes, In Selected Topics in Modelling and Control, Editor(s): Mikleš, J., Veselý, V., Slovak University of Technology Press, no. 8, pp. 70–73, 2012.

5 Kmeťová, J. – Vasičkaninová, A. – Dvoran, J.: The Continuous Stirred Tank Reactor – Using a Neuro-Fuzzy Approach for Control of the Reaction Mixture, In Selected Topics in Modelling and Control, Editor(s): Mikleš, J., Veselý, V., Slovak University of Technology Press, no. 8, pp. 80–83, 2012.

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8 Závacká, J. – Bakošová, M.: Graphical method for robust PID controllers design, In Selected Topics in Modelling and Control, Editor(s): Mikleš, J., Veselý, V., Slovak University of Technology Press, no. 8, pp. 53–57, 2012.

IX.3 Article in journal

1 Bakošová, M. – Mészáros, A. – Klemeš, J. – Oravec, J.: Robust and Optimal Control Approach for Exothermic Reactor Stabilization. Theoretical Foundations of Chemical Engineering, no. 46, pp. 740–746, 2012.

2 Bakošová, M. – Oravec, J.: Robust Model Predictive Control of Heat Exchangers. Chemical Engineering Transactions, no. 29, pp. 1465–1470, 2012.

3 Bakošová, M. – Oravec, J. – Matejičková, K.: Model Predictive Control-Based Robust Stabilization of a Chemical Reactor. Chemical Papers, 2012.

4 Blahová, L. – Dvoran, J. – Kmeťová, J.: Neuro-fuzzy control design of processes in chemical technologies. Archives of Control Sciences, no. 2, vol. 22, pp. 233–250, 2012.

5 Foley, G. – Paulen, R. – Fikar, M. – Kovacs, Z. – Czermak, P.: Comments on "Diafiltration under condition of quasi-constant membrane surface concentration" by R. Field [J. Membr. Sci. 383 (1–2) (2011) 301–302]. Journal of Membrane Science, vol. 390-391, pp. 285–285, 2012.

6 Kalúz, M. – Čirka, Ľ. – Fikar, M.: Virtual and Remote Laboratories in Process of Control Education.International Journal of Online Engineering, no. 1, vol. 8, pp. 8–13, 2012.

7 Kvasnica, M. – Fikar, M.: Clipping-Based Complexity Reduction in Explicit MPC. IEEE Transactions on Automatic Control, no. 7, vol. 57, pp. 1878–1883, 2012.

8 Oravec, J. – Bakošová, M.: Robust Constrained MPC Stabilization of a CSTR. Acta Chimica Slovaca, no. 2, vol. 5, pp. 153–158, 2012.

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11 Števek, J. – Szűcs, A. – Kvasnica, M. – Fikar, M. – Kozák, Š.: Two steps piecewise affine identification of nonlinear systems. Archives of Control Sciences, no. 4, vol. 22, pp. 371–388, 2012.

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13 Závacká, J. – Bakošová, M. – Matejičková, K.: Robust PID controller design for unstable processes with parametric uncertainty. Procedia Engineering, vol. 42, pp. 1572–1578, 2012.

IX.4 Article in conference proceedings

1 Bakošová, M. – Oravec, J.: MPC Based Robust Stabilization of a Chemical Reactor. Editor(s): Markoš, J., In Proceedings of the 39th International Conference of Slovak Society of Chemical Engineering, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 5–16, 2012.

2 Bakošová, M. – Oravec, J.: MPC Based Robust Stabilization of Uncertain Plants. In Proceedings of 13th International Carpathian Control Conference, Podbanske, Slovakia, pp. 13–18, 2012.

3 Bakošová, M. – Oravec, J.: An On-line Robust MPC Based on Nominal Optimization and Parameter-Depended Lyapunov Functions. In VOCAL 2012, Program and Abstracts, vol. 5, pp. 80–82, 2012.

4 Blažek, S. – Kvasnica, M.: Polygonic Representation of Explicit Model Predictive Control in Two Dimensions. Editor(s): Ivan Taufer, Daniel Honc, Milan Javurek, In Proceedings of the 10th International Scientific - Technical Conference Process Control 2012, University of Pardubice, Kouty nad Desnou, Czech Republic, 2012.

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6 Jelemenský, M. – Petáková, L. – Paulen, R. – Fikar, M.: Comparative Study in Dynamic Optimization of Emulsion Polymerization Reactor. Editor(s): Ivan Taufer, Daniel Honc, Milan Javurek, In Proceedings of the 10th International Scientific - Technical Conference Process Control 2012, University of Pardubice, Kouty nad Desnou, Czech Republic, pp. C013b – 1–C013b – 11, 2012.

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12 Klaučo, M. – Kvasnica, M.: Modeling of Networked Systems in Simulink. Editor(s): Ivan Taufer, Daniel Honc, Milan Javurek, In Proceedings of the 10th International Scientific - Technical Conference Process Control 2012, University of Pardubice, Kouty nad Desnou, Czech Republic, 2012.

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17 Kvasnica, M. – Gondhalekar, R. – Fikar, M.: A hierarchical design methodology for implementing safety-critical constrained controllers with guaranteed stability and failure detection. In IEEE Conference on Decision and Control, Maui, Hawaii, pp. 1214–1219, 2012.

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IFAC Nonlinear Model Predictive Control Conference, pp. 400–405, 2012.

19 Kvasnica, M. – Hledík, J. – Fikar, M.: Reducing the Memory Footprint of Explicit MPC Solutions by Partial Selection. In IEEE Conference on Decision and Control, Maui, Hawaii, pp. 4537–4542, 2012.

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24 Paulen, R. – Benyahia, B. – Latifi, M. A. – Fikar, M.: Dynamic Simulation of Hybrid Differential Algebraic Systems Using GPROMS: Case Study in Emulsion Polymerization. Editor(s): Ivan Taufer, Daniel Honc, Milan Javurek, In Proceedings of the 10th International Scientific - Technical Conference Process Control 2012, University of Pardubice, Kouty nad Desnou, Czech Republic, pp. C013a – 1–C013a – 14, 2012.

25 Paulen, R. – Fikar, M. – Foley, G. – Kovacs, Z. – Czermak, P.: Time Optimal Control of Batch Membrane Processes. Editor(s): Kozák, Š, Kozáková, A., Rosinová, A., In Kybernetika a informatika: Medzinárodná konferencia SSKI SAV, STU v Bratislave, 2012.

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Machine Intelligence and Informatics, IEEE, vol. 10, pp. 383–388, 2012.

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