**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: S. Blažek, Ľ. Čirka, J. Mikleš, M. Mojžišová, R. Paulen, J. Števek)

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# 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 2011.

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.

# III STAFF

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Neural Networks, Modelling and Control of Biochemical Processes

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# IV TEACHING AND RESEARCH LABORATORIES

## *IV.1 Teaching Laboratories*

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

## *IV.2 Research Laboratories*

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

# V. EDUCATIONAL ACTIVITIES

## *V.1 Bachelor Study*

### 1st semester (autumn)

| | | |
|---|---|---|
| Computer Based Data Processing | 0/0/2 | Oravec, Kalúz, Karšaiová, Kmeťová, Rauová |
| Programming of Network Application | 1/0/2 | Čirka |

### 2nd semester (spring)

| | | |
|---|---|---|
| Computer Based Data Processing | 0/0/2 | Karšaiová |
| Information Engineering and Systems | 1/2/0 | Čirka, Kalúz, Szücs |
| Operating Systems | 1/2/0 | Fikar, Podmajerský, Valo, Paulen |
| Optimisation | 2/3/0 | Dvoran, Blahová |

### 4th semester (autumn)

| | | |
|---|---|---|
| Modelling | 2/0/3 | Vasičkaninová, Závacká, Oravec |

### 4th semester (spring)

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

### 5th semester (autumn)

| | | |
|---|---|---|
| Process Control | 2/0/0 | Bakošová |
| Laboratory Exercises of Process Control | 0/0/2 | Karšaiová |
| Design of Information and Control Systems | 2/3/0 | Kvasnica, Valo |

### 6th semester (autumn)

| | | |
|---|---|---|
| Process Control | 2/0/0 | Bakošová |
| Laboratory Exercises of | 0/0/2 | Karšaiová |

Process Control

### 6th semester (spring)

| | | |
|---|---|---|
| Bachelor Projects | 0/0/9 | Bakošová, Fikar, Kvasnica, Karšaiová, Vasičkaninová, Valo, Závacká |
| Process Control | 2/0/0 | Bakošová |
| Laboratory Exercises of Process Control | 0/0/2 | Karšaiová, Oravec, Rauová, Závacká, Blahová |
| Computer Based Data Processing | 0/0/2 | Karšaiová |
| Integrated Control in Process Engineering | 2/0/3 | Karšaiová |
| Information Engineering and Systems | 1/2/0 | Čirka |
| Laboratory Exercises of Information Engineering and Systems | 0/0/2 | Kalúz |

## *V.2 Master Study*

### 1st semester (autumn)

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

## 2nd semester (spring)

| | | |
|---|---|---|
| Industrial Control and Information Systems I | 2/0/1 | Kvasnica, Valo |
| Identification | 2/0/2 | Čirka, Fikar |
| Automatic Control Theory II | 3/0/2 | Mikleš, Čirka |
| Semestral Project II | 0/0/3 | Bakošová, Fikar, Paulen Karšaiová, Kvasnica |
| Information Technologies II | 1/1/0 | Čirka |
| Technological Process Control | 1/1/0 | Dvoran |
| Algorithms and Programming | 1/2/0 | Závacká, Valo |
| Computer Based Data Processing | 0/0/2 | Karšaiová |

## 3rd semester (autumn)

| | | |
|---|---|---|
| Automatic Control Theory III | 3/0/2 | Fikar, Rauová, Závacká |
| Industrial Control and Information Systems II | 2/0/2 | Kvasnica, Szücs |
| Optimization of Processing and Production | 2/0/2 | Dvoran |
| Information Technologies II | 1/1/0 | Čirka |
| Diploma Project | 0/0/4 | Bakošová, Fikar, Kvasnica, Závacká Vasičkaninová, Karšaiová, Paulen |

## 4th semester (spring)

| | | |
|---|---|---|
| Model Predictive Control | 2/0/1 | Kvasnica, Rauová |
| Intelligent Control | 2/0/1 | Dvoran |
| Robust Control | 2/0/1 | Bakošová |
| Diploma Thesis | 0/0/17 | Čirka, Kvasnica, Bakošová |

Vasičkaninová

## V.3 PhD Study

**1st semester (autumn)**

| | | |
|---|---|---|
| Automatic Control Theory (Selected topics) | 4/0/0 | Mészáros |

**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, 2nd and 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 and 4th semester)**

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

mathematical models of continuous stirred tank reactors. Dynamic and static behaviour of processes.

## Operating Systems (1h/week, 2nd and 4th semester)

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

## Process Control (2h/week, 5th and 6th semester)

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

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

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

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

Feedback and 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.

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

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

## Information Engineering and Systems (1h/week, 1st 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 and 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, observabiliy 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, 2nd semester)

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

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

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)

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

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

Application of optimization methods for solving of optimization problems of 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.

## Algorithms and Programming (1h/week, 2nd semester)

Objective of the course is to introduce simple approaches to synthesis of logic control systems as well as their implementation on common industrial control systems. The course is divided into two major parts. The first one covers synthesis of simple controllers based on logic rules, their representation using finite state machines, as well as their implementation in Stateflow. The second

part is devoted to implementation of logic control on Programmable Logic Controllers using Ladder logic.

### 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, 2nd and 6th semester)

MATLAB/Simulink as a tool for system simulation, MATLAB – Control toolbox. Filtration of signals, analogue and digital filters, MATLAB – Signal

processing toolbox. MS Excel as a tool for data processing. Data processing by tables, data visualization by graphs, analytical tools in MS Excel, statistics in MS Excel. Origin as a tool for data visualization and processing.

## Optimisation (3h/week, 2nd semester)

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

## Laboratory Exercises of Process Control (2h/week, 5th and 6th semester)

MATLAB/Simulink as a simulation tool for 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 1/0537/10: Control of Chemical and Biochemical Processes with Uncertainties (M. Bakošová)

The scientific project deals with development of advanced control methods for systems with uncertainties and focuses on processes typical for chemical and food technologies, as e.g. chemical reactors, biochemical reactors, distillation columns, and others. Development of methods of robust analysis, robust stabilization, robust control and predictive control of systems with uncertainties constitutes the core of the project. Computational requirements and practical use will be taken into account in the design of algorithms. Designed algorithms, controllers, and control structures will be tested by simulations and in laboratory conditions.

Period: 2010-2011

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

The project deals with research and development of modern optimal control and optimisation methods and focuses into processes typical in chemical and

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

Period: 2009-2011

## 4. KEGA 3/7245/09*:* Development of Virtual and Remote Experiments for a Network of on-line Laboratories (M. Fikar)

The aim of the project is to continue in previous successful cooperation in development of virtual laboratories and to create virtual and remote experiments in measurement, control, and communication infrastructure based on information and communication technologies. Created experiments improve access to laboratories up to 24/7, support distance and electronic educational forms, help to handicapped people. The cooperation within the network will compare results of all groups.

Period: 2009-2011

## 5. APVV LPP-0092-07*:* Model Predictive Control of Hybrid Systems (M. Kvasnica)

The aim of this project is to extend the knowledge about parametric solutions to MPC problems for the class of hybrid systems. This involves, among other tasks, design of new algorithms for synthesis of robust control laws for the class of hybrid systems and new methods for state estimation for such systems. Modeling of compositional hybrid systems will be investigated as well. The goal is to create a software package which provides these algorithms to a broad range of users.

Period: 2008-2011

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

The project is focused on research in the areas of methods, algorithms and means for modelling and identification of technological units in process

industries, as well as on design and implementation of algorithms for synthesis, analysis and final implementation of control systems to aforementioned processes. Partial methods and algorithms will be designed with high focus on effectiveness of their respective implementation, which will decrease the purchasing and operating costs of control systems for processes with heat and mass transfer that can be described by hybrid models.

Period: 2008-2011

### 7. 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. OPVaV-2008/4.1/01-SORO: Support for establishment of Centre of Excellence for Smart Technologies, Systems, and Services

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

Concentration of top research and education teams in smart technologies, systems, and services in Bratislava region. Improvement of technical infrastructure in research and development of smart technologies, systems, and services including modernisation of ICT infrastructure. Improvement of effectiveness in know-how transfer know-how between academic and industrial sphere in smart technologies, systems, and services. Integration increase in international cooperation in research and development of smart technologies, systems, and services.

Period: 1.5.2009-30.4.2011

## 2. 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

## 3. 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. NIL-I-007-d: Enhancing NO-SK Cooperation in Automatic Control

Partners:

- Slovak University of Technology in Bratislava: URPI FEI STU (prof. Huba coordinator), UAMAI SjF STU (prof. Rohaľ-Iľkiv), UIAM FCHPT STU (prof. Fikar)

- Norwegian University of Science and Technology Trondheim (prof. Skogestad, prof. Johansen, prof. Hovd)

By supporting broad spectrum of activities ranging from student mobilities at the MSc. and PhD. level, staff mobilities, organization of multilateral international summer school and conferences, joint development of teaching materials and publishing scientific publications, project is devoted to enhancing cooperation in academic research in the automatic control area in the partner institutions STU Bratislava and NTNU Trondheim and through them also at broader regional, national and international levels.

Period: 2010-2011

### 2. SK-HU 0023-08: Project of Slovak - Hungarian Scientific Cooperation

**Advanced Optimization and Control Strategies in Energy Saving Processes**

Partners:

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

- University of Pannonia, Veszprém, Hungary (F. Friedler, P. Varbanov, J. Klemeš).

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

Period: 2009-2011

# 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)

- LRGP-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)***

| | |
|---|---|
| Baluch, A. | Implementation of Simple Controllers on PLCs<br>(Kvasnica, M.) |
| Bugárová, K. | Design of Quizzes for the Course Process Dynamics and Control in LMS Moodle<br>(Bakošová, M.) |
| Černá, K. | Design of Control Systems Using Reduced Models<br>(Karšaiová, M.) |
| Juriga, I. | Programming of LEGO Robots in Linux<br>(Valo, R.) |
| Lacho, L. | IMC -PID controller design<br>(Vasičkaninová, A.) |
| Pačesa, J. | Regulation of Laboratory Chemical Reactor<br>(Závacká, J.) |
| Sodomová, E. | Visualization of technological processes in industry using SCADA / HMI systems<br>(Valo, R.) |
| Štefánik, M. | Using of PID Controller for Control of Tanks for Liquid Storage<br>(Bakošová, M.) |
| Šugár, M. | Control by industrial Control system using SIMATIC<br>(Valo, R.) |
| Szabová, E. | Design of Quizzes for the Course Modelling in LMS Moodle<br>(Bakošová, M.) |

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

## *VIII.2 Graduate Theses (MS Degree)*

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

Babulíková, M. Robust PID Controller Design for Systems with Parametric uncertainty
(Bakošová, M.)

Bodnár, P. Development of Applications for Virtual Laboratory
(Čirka, Ľ.)

Chroustová, K. Implementation of Controllers on the B&R X20 Control System
(Kvasnica, M.)

Dubovský, D. Web Application Development Using the MVP Framework Nette
(Čirka, Ľ.)

Grancová, J. Control of Water Tanks using the FOXBORO Control System
(Kvasnica, M.)

Mareková, P. Control of Time-Delay Processes
(Bakošová, M.)

Mikušová, K. Using of Software UniSim Design for Process Modelling and Control
(Bakošová, M.)

Schmidt, D. Utilization of MATLAB Builder JA for Creating Virtual Laboratory
(Čirka, Ľ.)

Smižíková, J. Control of a Liquid-Mass System by the B&R X20 Control System
(Kvasnica, M.)

| | |
|---|---|
| Sónak, M. | Fuzzy controller design for integrating plants<br>(Vasičkaninová, A.) |
| Timuľák, V. | Robust fuzzy controller design for system with uncertainties<br>(Vasičkaninová, A.) |
| Tomeček, F. | Polynomial Methods for Control Systems Design<br>(Vasičkaninová, A.) |
| Wenchich, J. | Fuzzy identification and control. Generation GUI<br>(Vasičkaninová, A.) |

# IX. PUBLICATIONS

## *IX.1 Books*

1 Fikar, M.: Moodle 2: príručka učiteľa, FCHPT STU v Bratislave, Radlinského 9, 812 37 Bratislava, 2011.

2 Huba, M. – Skogestad, S. – Fikar, M. – Hovd, M. – Johansen, T. A. – Rohaľ-Ilkiv, B.: Selected Topics on Constrained and Nonlinear Control. Workbook, STU Bratislava - NTNU Trondheim, 2011.

3 Huba, M. – Skogestad, S. – Fikar, M. – Hovd, M. – Johansen, T. A. – Rohaľ-Ilkiv, B.: Selected Topics on Constrained and Nonlinear Control. Textbook, STU Bratislava - NTNU Trondheim, 2011.

## *IX.2 Chapter or pages in book*

1 Bakošová M.: Study at the FCFTSTU in Bratislava and possibilities of emplyment *(in Slovak)*, In *Katalýza v bežnom živote*, Nakladateľstvo STU, Bratislava, pp. 7–18, 2011.

2 Karšaiová, M. – Bakošová, M. – Vasičkaninová, A.: Robust Control Design of a Nonlinear System with Unstructured Uncertainties, In *Selected Topics in Modelling and Control*, Editor(s): J. Mikleš, V. Veselý, Slovak University of Technology Press Bratislava, no. 7, pp. 24–27, 2011.

3 Kvasnica, M.: Multi-Parametric Toolbox, In *Selected Topics on Constrained and Nonlinear Control. Workbook*, STU Bratislava - NTNU Trondheim, pp. 101–170, 2011.

4 Kvasnica, M. – Rauová, I. – Gyurki, Š. – Fikar, M.: Least Invasive Stabilizing Correction of Arbitrary Controllers, In *Selected Topics in Modelling and Control*, Editor(s): J. Mikleš, V. Veselý, Slovak University of Technology Press Bratislava, no. 7, pp. 13–15, 2011.

5 Kvasnica, M. – Fikar, M. – Čirka, Ľ. – Herceg, M.: *Complexity Reduction in Explicit Model Predictive Control*, In *Selected Topics on Constrained and Nonlinear Control. Textbook*, STU Bratislava - NTNU Trondheim, pp. 241–288, 2011.

6 Mikleš, J. – Čirka, Ľ. – Fikar, M.: H2 MIMO Controller with Integral Action, In *Selected Topics in Modelling and Control*, Editor(s): J. Mikleš, V. Veselý, Slovak University of Technology Press Bratislava, no. 7, pp. 7–12, 2011.

7 Szűcs, A. – Kvasnica, M. – Fikar, M.: Data Compression Techniques for Complexity Reduction in Explicit MPC, In *Selected Topics in Modelling and Control*, Editor(s): J. Mikleš, V. Veselý, Slovak University of

Technology Press Bratislava, no. 7, pp. 18–23, 2011.

8 Vasičkaninová, A. – Bakošová, M. – Karšaiová, M.: Neural Network Predictive Control and Neuro-Fuzzy Control of Heat Exchanger, In *Selected Topics in Modelling and Control*, Editor(s): J. Mikleš, V. Veselý, Slovak University of Technology Press Bratislava, no. 7, pp. 28–34, 2011.

9 Závacká, J. – Bakošová, M.: Robust PI Controller for Control of a Laboratory Process with Uncertainties, In *Selected Topics in Modelling and Control*, Editor(s): J. Mikleš, V. Veselý, Slovak University of Technology Press Bratislava, no. 7, pp. 35–39, 2011.

## *IX.3 Article in journal*

1 Bakošová, M. – Mészáros, A. – Klemeš, J. – Oravec, J.: Comparison of Robust and Optimal Approach to Stabilization of CSTRs. *Chemical Engineering Transactions*, vol. 25, pp. 99–104, 2011.

2 Dostál, P. – Bakošová, M. – Vojtěšek, J. – Bobál, V.: Adaptive nonlinear control of a continuous stirred tank reactor. *Chemical Papers*, no. 5, vol. 65, pp. 636–643, 2011.

3 Kačur, M. – Bakošová, M. – Terpák, J.: Matlab GUI for High-Performance Liquid Chromatography. *POSTERUS.sk*, no. 3, vol. 4, pp. 1–10, 2011.

4 Kalúz, M. – Čirka, Ľ. – Fikar, M.: Remote Experiment in Control Education. *AT&P Journal Plus*, no. 2, pp. 50–54, 2011.

5 Cseko, L. – Kvasnica, M. – Lantos, B.: Analysis of the explicit model predictive control for semi-active suspension. *Periodica Polytechnica*, no. 54, vol. 2010, pp. 41–58, 2011.

6 Kvasnica, M. – Löfberg, J. – Fikar, M.: Stabilizing polynomial approximation of explicit MPC. *Automatica*, no. 10, vol. 47, pp. 2292–2297, 2011.

7 Oravec, J. – Bakošová, M.: PIDTOOL 2.0 – Software for Step- Response-Based Identification and PID Controller Tuning. *AT&P Journal Plus*, no. 2, pp. 61–66, 2011.

8 Paulen, R. – Fikar, M. – Kovacs, Z. – Czermak, P.: Process optimization of diafiltration with time-dependent water adding for albumin production. *Chemical Engineering and Processing: Process Intensification*, no. 8, vol. 50, pp. 815–821, 2011.

9 Paulen, R. – Foley, G. – Fikar, M. – Kovacs, Z. – Czermak, P.: Minimizing the process time for ultrafiltration/diafiltration under gel polarization conditions. *Journal of Membrane Science*, no. 1-2, vol. 380, pp. 148–154, 2011.

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11 Števek, J. – Kozák, Š.: Fuzzy control in Xenta systems by Schneider Electric (in Slovak). *iDB Journal*, no. 2, vol. 2011, pp. 24–26, 2011.

12 Vasičkaninová, A. – Bakošová, M.: Intelligent Control of Heat Exchangers. *Chemical Engineering Transactions*, vol. 25, pp. 165–170, 2011.

13 Vasičkaninová, A. – Bakošová, M. – Mészáros, A. – Klemeš, J.: Neural network predictive control of a heat exchanger. *Applied Thermal Engineering*, vol. 31, pp. 2094–2100, 2011.

14 Vasičkaninová, A. – Bakošová, M.: Neuro-fuzzy Control of Integrating Processes. *Acta Montanistica Slovaca*, no. 1, vol. 16, pp. 74–83, 2011.

15 Matušů, R. – Závacká, J. – Prokop, R. – Bakošová, M.: The Kronecker Summation Method for Robust Stabilization Applied to a Chemical Reactor. *Journal of Control Science and Engineering*, vol. 2011, 2011.

16 Závacká, J. – Bakošová, M.: PI Controller Design for Laboratory Process with Uncertainties. *AT&P Journal Plus*, no. 2, pp. 73–77, 2011.

17 Závacká, J. – Blahová, L. – Bakošová, M. – Dvoran, J.: Advanced Control of a Mixing Process. *Acta Chimica Slovaca*, no. 2, vol. 4, pp. 18–32, 2011.

## *IX.4 Article in conference proceedings*

1 Dostál, P. – Gazdoš, F. – Bobál, V. – Bakošová, M.: Nonlinear adaptive control of a chemical reactor. In *Recent Researches in Automatic Control - 13th WSEAS International Conference on Automatic Control, Modelling and Simulation, ACMOS'11*, Lanzarote, Canary Islands, pp. 45–50, 2011.

2 Bakošová, M. – Oravec, J. – Kačur, M.: Software for Robust Stabilization of Systems with Parametric Uncertainties. Editor(s): Kozáková, A., In *ELITECH'11, 13th Conference of Doctoral Students*, Nakladateľstvo STU, Slovak University of Technology in Bratislava, Bratislava, Slovakia, vol. 13, pp. 09_Kacur, 2011.

3 Bakošová, M. – Oravec, J. – Kačur, M. – Závacká, J.: Stabilization of chemical reactors using robust and optimal controllers. Editor(s): Markoš, J., In *Proceedings of the 38th International Conference of Slovak Society of Chemical Engineering*, Slovak Society of Chemical Engineering, Tatranské Matliare, Slovakia, pp. 988–997, 2011.

4 Bakošová, M. – Oravec, J. – Kačur, M.: Solution of a Robust Stabilization Problem Using YALMIP and Robust Control Toolboxes. Editor(s): Fikar, M., Kvasnica. M., In *Proceedings of the 18th International Conference on Process Control*, Slovak University of Technology in Bratislava, Tatranská Lomnica, Slovakia, pp. 326–332, 2011.

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6 Bakošová, M. – Oravec, J.: Visual and Useful Software for PID Controller Design. Editor(s): Petr Byron, In *19th Annual Conference Proceedings: Technical Computing Prague 2011*, Humusoft s.r.o., pp. 014_bakosova, 2011.

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10 Čirka, Ľ. – Fikar, M.: LMS Moodle v2.0 - Random Assignment. Editor(s): Sojka, P., Kviza, M., In *Sborník 7. ročníku konference o elektronické podpoře výuky SCO 2011*, Muni Press, pp. 133–138, 2011.

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