

Doctoral Degrees in Process Control

Slavomír Blažek

May 26th, 2017

Supervisor: prof. M. Fikar. Title of the PhD thesis: *Optimal path planning problem for heterogenous multi-vehicle systems*. The thesis considers a path planning problem for heterogeneous vehicles. Such vehicle consist of two parts which have the ability to move individually. One of them is faster, but has shorter range and is therefore required to keep in a close distance to the main vehicle. The objective is to devise an optimal path of minimal length under the condition that the faster part of the heterogeneous system visits all desired waypoints exactly once.

S. Blažek currently works in private sector focusing on programming.



Martin Klaučo

August 17th, 2017

Supervisor: assoc. prof. M. Kvasnica. Title of the PhD thesis: *MPC-based Reference Governors: Theory and Applications*. The dissertation thesis deals with the improvement of the control performance of closed-loop systems via optimizing the setpoints for these closed-loops. Since the controllers in the closed-loops are usually of very simple structure, they do not provide constraint satisfaction nor enforce tracking properties. This thesis summarizes a concept of reference governors based on model predictive control, which provides optimal setpoints for the closed-loops.

M. Klaučo works as a postdoctoral researcher at our department.



Ján Drgoňa

August 17th, 2017

Supervisor: assoc. prof. M. Kvasnica. Title of the PhD thesis: *Model Predictive Control with Applications in Building Thermal Comfort Control*. The thesis deals with applications of model predictive control (MPC) on the building climate control problems. Many studies have proved that building sector can significantly benefit from replacing the current practice rule-based controllers (RBC) for more advanced control strategies like MPC. Despite this intensive research, the application of the MPC in practice is still in its early stages

J. Drgoňa is a postdoctoral at KU Leuven, at the Division of Applied Mechanics and Energy.



Deepak Ingole

September 29th, 2017

Supervisor: assoc. prof. M. Kvasnica. Title of the PhD thesis: *Embedded Implementation of Explicit Model Predictive Control*. The focus of this thesis lies on the embedded implementation of low-memory explicit MPC feedback laws. A novel memory reduction technique for low-memory explicit MPC laws is proposed. The technique is based on encoding all data as universal numbers (unums), which can be viewed as a more memory efficient extension of IEEE floating-point standard for representing real numbers

D. Ingole is a postdoc at University of Lyon.



International Grants

Embedded Optimal Control is a joint research project between the group of prof. M. Fikar and the group of prof. M. Mönnigmann from Department of Automatic Control and Systems Theory, Faculty of Mechanical Engineering of the Ruhr-Universität Bochum, Germany (A. von Humboldt Foundation, Germany).

Robust Model Predictive Control Meets Robotics is a joint mobility grant with participation of the group of assoc. prof. M. Kvasnica and the group of B. Houska, ShanghaiTech University, China (APVV, Slovakia) .

Real Time Optimal Process Control is joint research project between the research group of prof. M. Fikar and prof. M. A. Latifi from ENSIC, University of Lorraine, France (APVV, Slovakia).

Training in Embedded Predictive Control and Optimization (TEMPO) is an international PhD program for highly motivated young scientists financed by the European Commission - Framework Program 7, MC ITN, (7FP, EU).

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SLOVAK UNIVERSITY OF
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FACULTY OF CHEMICAL
AND FOOD TECHNOLOGY



Department of Information Engineering and Process Control

Dear co-workers, project colleagues, perspective partners, former members of the department,

As the year 2017 is nearing the end, it is time to reflect on achievements of members of our department. This year was the most successful in the modern history of our department, mainly in terms of the scientific activity. Our department together with the Institute of Automation, Measurement and Applied Informatics (Faculty of Mechanical Engineer-

ing) organized a TEMPO Summer School. Next, we were the lead organizer of the Process Control 2017 conference held in Štrbské Pleso, Slovakia.

One of the great privilege is to acknowledge intensive research activity of the members of our department. This year we have published the highest number of high-quality journal papers in one year, followed by nine papers presented at the IFAC World Congress. Four Ph.D. students graduated at our department from the

field of Process Control, which is again the highest number of graduates in our history.

I would like to thank my colleagues and partners for successful and pleasant collaboration. I sincerely hope for a future and even more involved participation in research, grants proposals and industrial cooperation in the year 2018.

Miroslav Fikar
head of the department



TEMPO Summer School 2017

Our department was the lead organizer of the TEMPO Summer School, on July 17-21, 2017. The topic of this intensive training was the *Hardware Implementation of Embedded Optimisation* with the aim to give hands-on experience in implementation of model predictive controllers (MPC) on embedded hardware like field-programmable gateway arrays

(FPGAs), programmable logic controllers (PLCs), and Arduino microcontrollers. The course has been designed for both industrial and academic researchers as well as for master and Ph.D. students of engineering, computer science, mathematics, and physics.

Invited speakers were Eric Kerrigan (Imperial College, London), Michal Kvasnica, and Gergely Takács (Slovak University of Tech-

nology in Bratislava). On the first day, M. Kvasnica presented model predictive control with the con-



nection to PLC programming; next E. Kerrigan discussed thoroughly the topic of MPC on FPGAs and on the third day G. Takács gave a seminar entitled as MPC on Arduino. Last two days 51 participants from more than ten countries worked on projects, which were completed by presentations. An evening reception was held for the speakers and participants at the Danube Brewery located on a boat on the Danube river in Bratislava.



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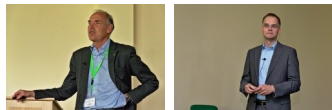


Process Control 2017



Our department was the lead organizer of the 21st International Conference on Process Control 2017 held in Štrbské Pleso, Slovakia June 6-9, 2017. The objective of this three-day conference was to bring together theory-experts and control systems specialists, to discuss the new possibilities of techniques, design procedures and instru-

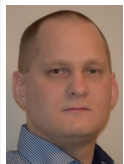
ments in process control projects. The conference proceedings has been opened with a plenary lecture titled as Economic Plantwide Control given by S. Skogestad. On the second day, M. Mönnigmann gave the plenary talk on Constructive Nonlinear Dynamics in Optimisation and Process Systems. The highlight of the pro-



ceedings was a tutorial workshop by B. Houska on the topic of Distributed Optimization and Control with ALADIN. The conference was organized into nine regular sessions and one invited session covering, among other fields, control system design, model predictive control, optimization, industrial automation.

New researchers

Radoslav Paulen received his PhD in process control from Slovak University of Technology in Bratislava. After 5-year stay at TU Dortmund joined our department. His main research interests include mainly dynamic optimization and guaranteed parameter estimation.



Martin Klaučo received his PhD in process control from Slovak University of Technology in Bratislava. He continues to work at our department as a postdoctoral researcher funded by our faculty. He focuses mainly on model predictive control and machine learning approaches in control theory.

Martin Kalúz received his PhD from process control from Slovak University of Technology in Bratislava. After 3-year teaching position at our department continues as a researcher under the grant Machine Learning and Artificial Intelligence in Process Control and Autom-



Workshop in Valtice, CZ



Members of the department attended the three-day workshop in Valtice, Czech Republic.

The workshop was open by the head of our department, prof. M. Fikar. Main topics of the first-day discussions

evolved around the status of research and teaching activities at our department. The second day was devoted to social activities. The highlight of the second day was a lecture of Dr. R. Paulen titled as "Optimal Operation of Membrane Processes". On the third day of the workshop, members of the department attended a lecture given by P. Bakaráč on the topic of "Model Predictive Control of System with Fast Dynamics". Discussions on this day also focused on software and hardware infrastructure at our department.

Master Theses:

Bakaráč, P.: Development and Control of Inverted Pendulum (in Slovak).

Batárová, K.: Advanced control methods of pH in a chemical reactor (in Slovak).

Jakabšic, J.: Development of Graphical User Interface for Intelligent Room.

Koniar, S.: Support control systems based on MPC (in Slovak).

Mikušová, N.: Development of Software Tools for Automation and Control in JULIA Environment (in Slovak).

Mišenko, M.: Stabilisation of Column Feed using APC.

Awards

Michal Kvasnica has been awarded with Prize of the Literary Fund of the Slovak Republic for the most frequently cited article and Prize of the Literary Fund of the Slovak Republic for the second highest number citations in 3 years.



Martin Klaučo has received the Award of the Rector of STU in Bratislava for his achievements during his Ph.D. studies. Martin also received the Award of the Dean of Faculty of Food and Chemical Technology for extensive publication record.

Dr. R Paulen has received an award 'Scientist of the year at STU' in the category young scientist.

Participation at Conferences

Nine papers co-authored by members of our department were presented on IFAC World Congress in Toulouse, France.

M. Fikar, R. Paulen, and J. Oravec attended the 10th World Congress on Chemical Engineering in Barcelona, Spain.

Members of our department co-authored 13 papers which were presented at the 21st International Conference on Process Control in Štrbské Pleso.

Domestic Research Grants

Optimal Control for Process Industries is a research project funded by the APVV organization. The principal investigator is prof. M. Fikar.

Energy Efficient Process Control is a VEGA research project where the principal investigator is prof. M. Fikar.

Control of Energy Intensive Processes with Uncertainties in Chemical Technologies and Biotechnologies is a VEGA research project where the principal investigator is assoc. prof. M. Bakošová.

Verifiably Safe Optimal Control is a VEGA research project where the principal investigator is assoc. prof. M. Kvasnica.

Machine Learning and Artificial Intelligence in Process Control and Automation is a postdoc research stay financed by the Slovak University of Technology in Bratislava. The principal investigator is assoc. prof. M. Kvasnica.

Advanced Optimal and Safety Oriented Control of Energy-Intensive Processes is an Internal Grant of the Slovak University of Technology in Bratislava for young researchers. The principal investigator is Dr. M. Klaučo.

Journal papers 2017

Drgoňa, J. – Klaučo, M. – Janeček, F. – Kvasnica, M.: Optimal control of a laboratory binary distillation column via regionless explicit MPC. *Computers & Chemical Engineering*, pp. 139–148, 2017.

Gottu Mukkula, A. R. – Paulen, R.: Model-based design of optimal experiments for nonlinear systems in the context of guaranteed parameter estimation. *Computers & Chemical Engineering*, pp. 198–213, 2017.

Klaučo, M. – Kalúz, M. – Kvasnica, M.: Real-time implementation of an explicit MPC-based reference governor for control of a magnetic levitation system. *Control Engineering Practice*, pp. 99–105, 2017.

Klaučo, M. – Kvasnica, M.: Control of a boiler-turbine unit using MPC-based reference governors. *Applied Thermal Engineering*, pp. 1437–1447, 2017.

Nguyen, N. A. – Oлару, S. – Rodríguez-Ayerbe, P. – Kvasnica, M.: Convex liftings-based robust control design. *Automatica*, pp. 206–213, 2017.

Oravec, J. – Klaučo, M. – Kvasnica, M. – Löfberg, J.: Computationally Tractable Formulations for Optimal Path Planning with Interception of Targets' Neighborhoods. *Journal of Guidance, Control, and Dynamics*, pp. 1221–1230, 2017.

Picard, D. – Drgoňa, J. – Kvasnica, M. – Helsen, L.: Impact of the controller model complexity on model predictive control performance for buildings. *Energy and Buildings*, pp. 739–751, 2017.

Sharma, A. – Jelemenský, M. – Paulen, R. – Fikar, M.: Modeling and optimal operation of batch closed-loop diafiltration processes. *Chemical Engineering Research and Design*, pp. 198–210, 2017.

Vasičkaninová, A. – Bakošová, M. – Čirka, L. – Kalúz, M. – Oravec, J.: Robust Controller Design for a Laboratory Heat Exchanger. *Applied Thermal Engineering*, pp. 1297–1309, 2017.

Wenzel, S. – Paulen, R. – Beisheim, B. – Krämer, S. – Engell, S.: Market-Based Coordination of Shared Resources in Cyber-physical Production Sites. *Chemie Ingenieur Technik*, pp. 636–644, 2017.

