DEPARTMENT OF SYSTEMS AND CONTROL E-2

The Department of Systems and Control is engaged in research, development, applications and education across various areas of control technology. Its mission is "to bridge the gap between theory and practice". Hence, the research activities are relatively application oriented, and the content of the work is closely related to the needs of production companies. The activities of the department are focused on the research of new methods and algorithms for automatic control, the development of procedures and tools to support the design and construction of control systems, the development of specific measurement and control modules, and the development and construction of complete systems for the control and supervision of machines, devices and industrial processes.

Head:
Prof. Stanislav Strmčnik

The Department of Systems and Control is engaged in research, development, applications and education across various areas of control technology.

Basic and applied research

The basic and applied research during 2007 was devoted to four sub-areas: the analysis and control of complex systems and processes, fault detection and isolation, computer-integrated production control, and advanced implementation technology.

In the sub-area **analysis and control of complex systems and processes** our work was devoted to the development of some general-purpose methods. The research efforts in dynamic systems modelling of Gaussian process models were focused on methodology and the incorporation of prior knowledge in models (Fig.1). Gaussian process models were further used for control design in various control algorithms, among them in explicit model predictive control. In the area of predictive control the work was focused on parametric predictive controllers. Parametric optimization is used to shift the computational burden, associated with online optimization, offline. In the control loop it is only necessary to select the active linear control law from a table (Fig.2). This work was closely related with the EU 6FP CONNECT. We were also active in the research of the improved supervision of online identification of an adaptive controller by using pattern-recognition techniques and hybrid systems theory, as well as in the optimal tuning of controllers where a new "equalization" method was proposed for the tuning of PID and multivariable controllers.

New control methods and algorithms were also being developed on various specific problem domains. Within the international project PRISM a model of the polymerisation process was developed. The model will be used for process optimisation, with the aim to shorten the batch cycle. Within the international project PEGASE, a system for the automatic landing of aircraft and helicopters is being developed, which is completely autonomous and does not depend on any kind of infrastructure or equipment located outside the aircraft. The idea is to guide the aircraft using images, acquired by the camera, installed on the aircraft. In the control of wastewater-treatment processes, different alternatives to control nitrification and pre- and post-denitrification processes based on nutrient sensors were evaluated by simulation.

In the sub-area of **fault detection and isolation** work has been continued on the problem of spectral reconstruction from short time series by means of the Filter-Diagonalization method. Monte Carlo analysis revealed that the high resolution of the reconstructed spectral content could be achieved in the condition of short observation times and noise in the signal. Using the example of a bearing fault on an electrical motor, the algorithm demonstrated fast and accurate tracking of the instantaneous frequencies of the signal. Part of the activities was devoted to the development of algorithms for the supervision of processes and product quality on the basis of novel statistical modelling approaches. For the case of Gaussian process models, a fault-detection algorithm has been derived by making use of statistical decision making.

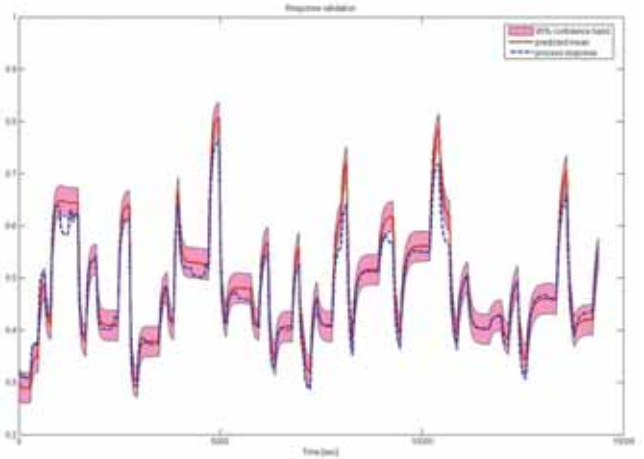

Figure 1: Comparison of a real-process response and its Gaussian process model.

The basic and applied research during 2007 was devoted to four sub-areas: the analysis and control of complex systems and processes, fault detection and isolation, computer-integrated production control, and advanced implementation technology.

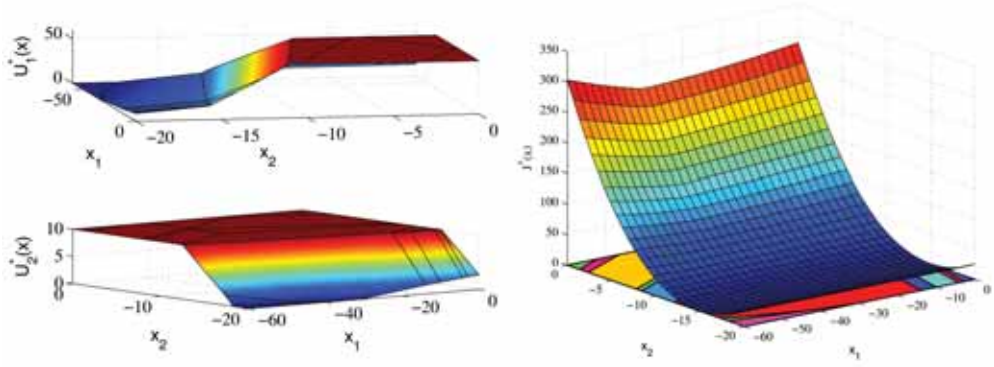

Figure 2: Surfaces of control signals and the optimal value function of a parametric predictive controller

In co-operation with the Centre for Tribology and Technical Diagnostics, University of Ljubljana, we contributed to the development of a laboratory test bed and experimental environment for the diagnosis of electrical machines and drives. The development of diagnostic algorithms based on the analysis of vibrations, electrical current and oil parameters is under way.

In cooperation with the Slovenian Ministry of Defence four projects in the area of fuel-cell-based system applications and the development of subsystems for fuel-cell power units are being performed.

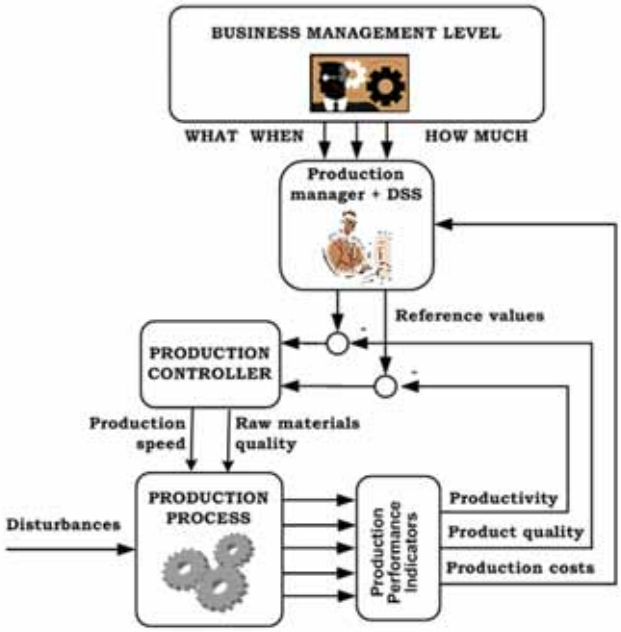

Figure 3: Hierarchical production control scheme for the polymerization plant in Mitol d.d.

Some members of the department are giving lectures and practical courses at the Faculty of Electrical Engineering, University of Ljubljana, the Faculty of Logistics, University of Maribor, the University of Nova Gorica, and the "Jožef Stefan" International Postgraduate School.

A part of the work related to this sub-area was devoted to the research of methods that enable an assessment of the state of a living organism, based on the level of coupling among oscillatory physiological signals, like ECG, EEG, respiratory effort, etc. In the past year we finished developing the measurement system and started with measurements on humans and rats. The work has been carried out in close connection with the international project BRACCIA.

Our research in the sub-area of **computer-integrated production control** was concentrated on the design and verification of a hierarchical production-control system. A concept for production control, using a reduced set of production-process parameters, was developed (Fig. 3), together with the corresponding control algorithms. For the production control of a batch-polymerization plant in the company Mitol, three algorithms have been evaluated: production control based on look-up tables, predictive control based on a simplified production model and production control based on an expert system. A number of simulation runs have been carried out in order to validate these control algorithms.

In the area of **advanced implementation technologies** a part of the activities was devoted to the development of a rapid-prototyping tool for the design and implementation of control algorithms. In this frame the identification of the parameters of the continuous second-order process model with time-delay has been included. The model has been used within an integrated Smith predictor.

The second part was related to methods and tools for control SW development. A more thorough definition was elaborated for the syntax and semantics of the domain-specific modelling language ProcGraph, which was previously developed in our department.

To fulfil the needs for the development of new electronic devices, further work on the environmentthat will enable the design of embedded control and digital signal processing systems, based on the ARM core microprocessors, was continued.

R&D projects for industry and other users

In cooperation with the **Slovenian Ministry of Defence** four projects in the area of fuel-cell-based system applications and the development of subsystems for fuel-cell power units are being performed (Fig. 4). In the frame of fuel-cell applications we were developing a fuel-cell-based auxiliary power-supply system, for increasing the autonomy of a military vehicle, and a demonstrational prototype of a mobile cogeneration fuel-cell-based system. In the frame of fuel-cell subsystems development we are a partner

involved in the design of a ceramic fuel reformer for PEM-type fuel cells and in the development of the experimental laboratory set-up for the testing and validation of various subsystems for PEM fuel cells.

Apart of the above-mentioned work, we were also very active in R&D projects for industry. For the company **DOMEL d.d.** we were working on upgrading the previously developed automatic diagnostic system for the end-quality control of electrical motors, and on the development of a control system for a gas- and air-delivery system for a fuel cell. For the company **GOAP** a new algorithm for calculating the room-temperature set-points in buildings was developed.

A new tool called PLCbatch (Fig. 5) for recipe-based batch-process control was developed in cooperation with the company **INEA**, based on the experience and results of our previous work on the development of the prototype tool LiteBatch. The new tool opens a new market segment of PLC-based batch-process control. Currently, with the aid of this tool, a process-control system in the paint-producing company **Color** is being developed. For the company **Danfoss-Trata,** hardware and software has been developed for the control of continuous and three-point valves. The implemented algorithms enable intelligent behaviour of the valves. In addition, some smaller projects were carried out for our traditional partners: the **Domžale-Kamnik wastewater-treatment plant**, and the **Cinkarna-Celje** chemical works.

Figure 4: Demonstration of the 7kW fuel-cell based power unit

A substantial part of our work was also devoted to final activities within the projects of the **Centre of Excellence for Advanced Control Technologies** (which includes 15 industrial and four academic partners), which is coordinated by our department, and on a large project (26 partners) entitled **"Advanced Control Technologies for Improving Competitiveness",** where we also played a substantial role in the coordination. The projects were co-financed by European structural funds.

Our paper on advanced control algorithms (listed under outstanding publications) was, in the first quarter of 2007, second, and, in the second quarter of the year, first on the list of the "Top 25 hottest articles" of the journal Control Engineering Practice.

Education and training activities

Some members of the department are giving lectures and practical courses at the Faculty of Electrical Engineering, University of Ljubljana, the Faculty of Logistics, University of Maribor, the University of Nova Gorica, and the "Jožef Stefan" International Postgraduate School. They also act as supervisors of M.Sc. and Ph.D. students. Special care was given to post-qualification training for engineers from industry. In 2007, three one-week courses were organized. These courses were organized in close cooperation with the Information Technologies Knowledge Transfer Centre at the Jožef Stefan Institute.

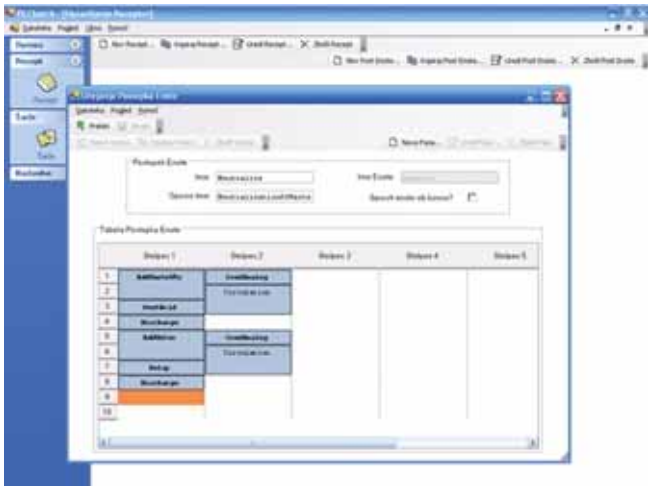

Figure 5: User interface of the PLCbatch tool (unit procedure recipe editing window)

Some outstanding publications in the past three years

1. Gerkšič, Samo, Dolanc, Gregor, Vrančić, Damir, Kocijan, Juš, Strmčnik, Stanko, Blažič, Sašo, Škrjanc, Igor, Marinšek, Zoran, Božiček, Miha, Stathaki, Anna, King, Robert E., Hadjinski, Mincho B., Boshnakov, Kosta. Advanced control algorithms embedded in a programmable logic controller. Control eng. pract.. [Print ed.], 2006, vol. 14, no. 8, pp. 935–948.
2. Stare, Aljaž, Vrečko, Darko, Hvala, Nadja, Strmčnik, Stanko. Comparison of control strategies for nitrogen removal in an activated sludge process in terms of operating costs: a simulation study. Water res. (Oxford). [Print ed.], 2007, vol. 41, no. 9, pp. 2004–2014.
3. Benko, Uroš, Petrovčič, Janko, Juričić, Đani, Tavčar, Jože, Rejec, Jožica. An approach to fault diagnosis of vacuum cleaner motors based on sound analysis. Mech. syst. signal process., 2005, vol. 19, pp. 427–445.

The most important technological achievements in the past three years

1. A control system for a magneto-focused plasma annealer (Gregor Dolanc, Samo Gerkšič)
2. A series of systems for the quality control of vacuum-cleaner motors (Janko Petrovčič, Gregor Dolanc, Bojan Musizza, Đani Juričić, Dejan Tinta, Uroš Benko, Stane Černe, Janez Grom, Miro Štrubelj)

Organization of conferences, congresses and meetings

1. Production management and information systems: continuing education (specialisation) course in Control Technology, Ljubljana, January 29 – February 2, 2007
2. Automation and information technology projects: continuing education (specialisation) course in Control Technology, Ljubljana, March 26 – 30, 2007
3. Building blocks for computer automation: continuing education (specialisation) course in Control Technology, Ljubljana, October 22 – 26, 2007

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THESES

Ph. D. Theses

1. Kristjan Ažman: Dynamic systems identification with Gaussian processes (Juš Kocijan)
2. Uroš Benko: Fault diagnosis of technical systems based on modern signal processing techniques (Đani Juričić)
3. Aljaž Stare: Optimal control of nitrogen removal in a biological wastewater treatment plant (Stanko Strmčnik)

B. Sc. Theses

1. Aleš Bajc: Application of programme module Scicos for graduate in engineering and management (Juš Kocijan)
2. Jernej Bratina: Graphic user interface for rolling line supervisory control (Juš Kocijan)
3. Tomaž Lukman: Model driven engineering in the domain of industrial control systems
4. Valentin Simonič: The assessment of system antropocentricity with dual design method for the control of neutralisation batch process (Juš Kocijan)
5. Igor Žiberna: Assembly and control design for hard coating assembly line (Juš Kocijan)

INTERNATIONAL PROJECTS

1. Design of Advanced Controllers for Economic, Robust and Safe Manufacturing Performance
   CONNECT, 6. FP, COOP-CT-2006, 031638
   EC; Dr. Constantinos Pantelides, Process Systems Enterprise Limited, London, Great Britain
   Dr. Samo Gerkšič, Dr. Vladimir Jovan
2. HelicoPter and aEronef naviGation Airborne System Experimentations
   PEGASE, 6. FP, AST5-CT-2006-030839
   EC; Bruno Pattin, Claire Lallemand, Dassault Aviation, Paris, France
   Prof. Stanko Strmčnik, Dr. Gregor Dolanc
3. Towards Knowledge - Based Processing Systems
   PRISM, 6. FP, MRTN-CT-2004-512233
   EC; Imperial College of Science Technology and Medicine, London, Great Britain
   Dr. Gregor Kandare
4. Explicit Nonlinear Model Predictive Control based on Gaussian Process Models
   Prof. Alexandra Grancharova, Institute of Control and System Research, Bulgarian Academy of Sciences, Sofia, Bulgaria
   Prof. Juš Kocijan
5. Bayesian Decision Making to support Change Detection in Complex Manufacturing Systems
   BI-CZ/07-08-011
   Ing. (Dipl.-Eng.) Phd Tatiana Valentine, Department of Adaprive Control, Institute of Information Theory and Automation, Prague, Czech Republic
   Prof. Đani Juričić
6. Analysis, Diagnosis and Control of Distributed Nonlinear Process Systems
   BI-HU/06-07/006
   Sc. Dr. Katalin Hangos, Computer and Automation Research Institute, Hungarian Academy of Sciences, Budapest, Hangary
   Prof. Đani Juričič
7. On-line Minitoring and Fault Diagnosis of Industrial Systems
   BI-MK/07-08-018
   Prof. Mile Stankovski, Faculty of Electrical Engineering, Skopje, The Republic of Macedonia
   Prof. Đani Juričič
8. 12 Channel Measurement System Cardio&Brain Signals and Set of Sensors and Electrodes
   Ulleval Universitetssykehus, Oslo, Norway
   Dr. Janko Petrovčič
9. Design of PID Controllers: Interchange of Technology and Experience - Second Part
   BI-PT/06-07-005
   Asst. Prof. José Paulo de Maura Oliveira, Engineering Department, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal
   Asst. Prof. Damir Vrančič
10. Building Virtual Communities for Research and Education in Automation and Control
    BI-SK/05-07-009
    Prof. Mikuláš Huba, Slovak University of Technology in Bratislava, Bratislava, Slovakia
    Asst. Prof. Damir Vrančič
11. 12 Channel Measurement System Cardio&Brain Signals and Set of Sensors and Electrodes
    Dr. Andrew F. Smith, University Hospitals of Morcambe Bay NHS Trust, Royal Lancaster Infirmary, Lancaster, Great Britain
    Dr. Janko Petrovčič
12. 12 Channel Measurement System Cardio&Brain Signals and POF to USB Converter
    1661AB040
    R. Lewsey, Lancaster University, Department of Physics, Lancaster, Great Britain
    Dr. Janko Petrovčič

R & D GRANTS AND CONTRACTS

1. Design of fault detection and isolation systems with application to quality assessment of electrical motors
   Asst. Prof. Đani Juričić
2. An intelligent system for condition monitoring of rotating machinery
   Asst. Prof. Đani Juričić
3. Optimization of HVAC systems using dynamic models
   Prof. Dr. Stanislav Strmčnik
4. Rapid prototyping of advanced control algorithms in industrial environment
   Asst. Prof. Damir Vrančič
5. Early detection of lung cancer in workers with asbestos disease
   Asst. Prof. Đani Juričić
6. Fuel cell based auxiliary power system for autonomous operation of military vehicles
   Dr. Janko Petrovčič

RESEARCH PROGRAM

1. Systems and control
   Prof. Dr. Stanislav Strmčnik

NEW CONTRACTS

1. Design and implementation of the 12 channel measurement system – Cardio&Brain
   University of Ljubljana
   Dr. Janko Petrovčič
2. Ddesign of electronic for intelligent valve drive
   Danfoss Trata d.o.o., Ljubljana
   Asst. Prof. Damir Vrančić
3. Mobile test laboratory with fuel cell power unit
   Domel, d.d., Železniki
   Dr. Vladimir Jovan
4. Development of demonstration prototype of mobile cogeneration fuel cell based system for military purposes
   Inea d.o.o., Ljubljana
   Dr. Vladimir Jovan
5. Development of demonstration prototype of mobile cogeneration fuel cell based system for military purposes
   Domel, d.d., Železniki
   Dr. Vladimir Jovan
6. Design and realisation of a control module
   Domel, d.d., Železniki
   Dr. Janko Petrovčič

VISITORS FROM ABROAD

1. prof. José Paulo de Maura Oliveira, Engineering Department, University of Trás-os-Montes e Alto Douro, Campus Universitário, Vila Real, Portugal, 20. – 27.7. 2007
2. prof. Mikuláš Huba, Slovak University of Technology in Bratislava, Bratislava, Slovakia, 19. 8. – 2. 9. 2007
3. dr. Pavel Ettler, Compureg Plzen, Plzen, Czech Republic
4. Peter Kurcik, Slovak University of Technology in Bratislava, Bratislava, Slovakia, 19. 8. – 2. 9. 2007
5. dr. Gabor Szederkenyi, Computer and Automation Research Institute, Hungarian Academy of Sciences, Budapest, Hungary, 9. – 15. 9. 2007
6. dr. Csaba Fazekas, Computer and Automation Research Institute, Hungarian Academy of Sciences, Budapest, Hungary, 9. – 15. 9. 2007
7. prof. David J. Murray-Smith, University of Glasgow, Department of Electronics and Electrical Engineering, Glasgow, Scotland, 11.9.2007.

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20. Bojan Musizza, B. Sc.
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23. Aleš Svetek, B. Sc.
24. Sebastjan Zorzut, M. Sc., *left 01.04.2007*

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25. Stanislav Černe, B. Sc.
26. Giovanni Godena, B. Sc.
27. Dr. Zoran Marinšek***

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