# 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.
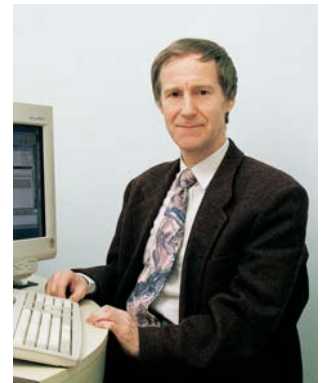
Head:
Prof. Stanislav Strmčnik

Basic and applied research

The basic and applied research during 2006 was devoted to three sub-areas: the analysis and control of complex systems and processes, fault detection and isolation, and computer-integrated production control.

The aim of the research in the sub-area **analysis and control of complex systems and processes** was to improve the existing algorithms and also to develop new algorithms for systems or process control. A part of the activities was devoted to tuning and optimising industrial controllers, where a new tuning method was developed, with which optimal disturbance rejection can be obtained. Using this approach, a control system for stereoscopic camera synchronization was designed (Fig. 1). The second research topic was related to Gaussian processes. Here, dynamic models were developed based on Gaussian process models with a fixed structure, which were used for the design of nonlinear explicit predictive control algorithms. The third topic was related to the research of supervision algorithms for adaptive controllers. Here, new concepts were developed that enable the effective and correct adaptation also in the presence of large, fast and non-measurable disturbances. Finally, in the control of wastewater-treatment processes, feed-forward and predictive control algorithms for nitrogen control were designed and tested on a wastewater-treatment benchmark (Fig. 2).

Nowadays, continuous quality control in manufacturing as well as in the processing industries and other high-technology systems has become a standard aid to better productivity and competitiveness. Therefore, **fault detection and isolation** is currently a fast-developing sub-area of research in the Department of Systems and Control that has a growing significance for our industrial partners. In 2006, applied research in the area of fault detection and isolation was focused on two main topics. The first one can be viewed as a continuation of the research in the area of the quality assessment of electrical motors. The main idea was to use the results of an online motor assessment in order to make statistical tests that can reveal incipient changes in product quality due to changes in the assembly line (Fig. 3). In the second topic, significant progress has been achieved in the area of signal reconstruction from short time series. The research was based on the adoption of the filter-diagonalization method and its reformulation in the dynamic system framework. By using Monte Carlo analysis new results were obtained showing that the quality of reconstruction monotonically degrades with an increasing signal-to-noise ratio and a decreasing observation time.

Our research in **computer-integrated production control** is aimed at enhancing existing manufacturing information and execution systems (MES) with functions for efficient decision making. In 2006, the development of a procedural model for a selected manufacturing system was continued. The model is designed as a functional building block of MES, supporting decision making that will use parameters of technology as well as production costs to help production managers optimise

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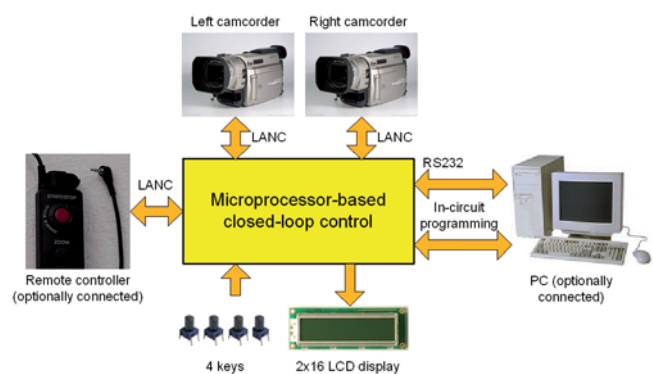

Figure 1: Block scheme of video and still cameras synchronizer (3D LANC Master).

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It is important to note that a substantial part of our basic and applied research is closely related to work in the EU's 6FP projects PRISM, CONNECT, and PEGASE.

production (Fig. 4). Based on the model and its simplification a predictive control algorithm was designed, and its performance was investigated. The second part of the activities within this sub-area was devoted to problems of the economic evaluation of computer-integrated production control systems and the evaluation of methods for the design and implementation of human-centred technology.

It is important to note that a substantial part of our basic and applied research is closely related to work in the EU's 6FP projects PRISM, CONNECT, and PEGASE.
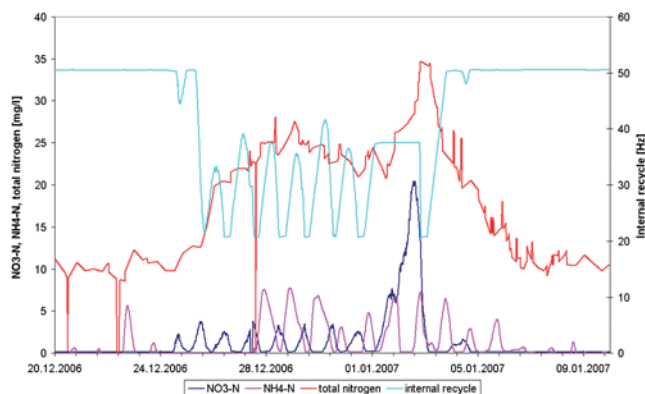

Figure 2: Control of nitrate nitrogen NO₃-N by manipulating the internal recycling at the Domžale-Kamnik wastewater-treatment pilot plant.

R&D projects for industry and other users

In 2006 our R&D activities were mainly related to projects initiated by industrial partners and co-financed by the European Regional Development Fund.

In the frame of the **Centre of Excellence for Advanced Control Technologies** (which includes 15 industrial and 4 academic partners), which is coordinated by our department, we have taken part in three R&D projects. The topics that were dealt with were mainly the following: the development of a control-loop tuning tool, the development of standardized control SW blocks, the development of specific control algorithms for waste-water treatment, the development of modules for vibro-acoustic analysis, and the conceptual design of information support for solving partially structured production management processes.

We have also played a substantial role in the coordination of a large project (26 partners) entitled **"Advanced Control Technologies for Improving Competitiveness"**. Within this project we were actively involved in various research and development sub-projects, for example, the conceptual design of additional functionalities for production management systems, the development of a prototype SW tool called LiteBatch, for batch process control, the development of a SW package for the optimal scheduling of batches in TiO_2 production, the conceptual design of methods and tools for supporting the life-cycle approach in automation projects, etc.

In addition to the above-mentioned large projects we have also worked on some other R&D projects.

In 2006 our R&D activities were mainly related to projects initiated by industrial partners and co-financed by the European Regional Development Fund.

For the companies PlasmaIt and PlasmaBull, a control system for the automatic control of a plasma-based wire-treating device was developed. The system controls and supervises all the parameters related to plasma, as well as the parameters of peripheral modules, such as temperatures, pressures, etc. For the company Domel d.d., a semi-automatic diagnostic system for the quality assessment of DOMUS-type vacuum-cleaner motors was designed and built, which was transferred to the PR of China, where a new Domel factory is established. Also, a new, completely automatic, diagnostic system for several types of motors was designed and b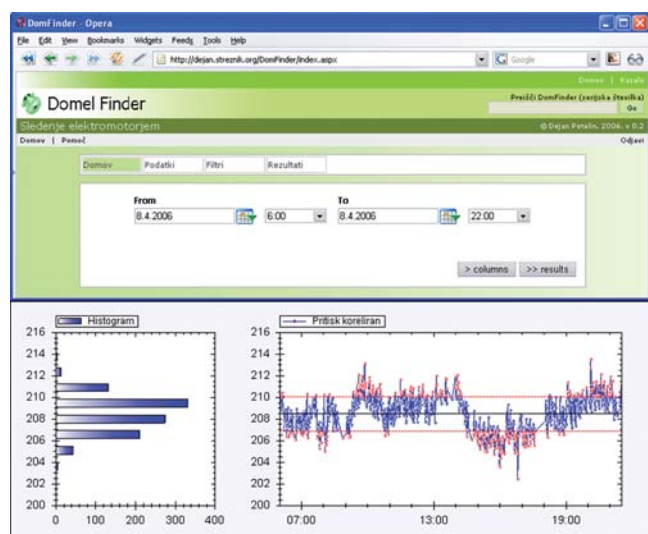uilt to increase the production capabilities at the Domel Company in Železniki. For the company GOAP a simple algorithm for calculating the room temperature set-points in buildings was developed. The algorithm changes the room-temperature set-points according to the thermal conditions in the building. In 2006, our long-term cooperation with the engineering company INEA continued. We were mainly engaged in defining a set of key performance indicators and the procedure for their calculation. The task was related to the development of the I4PROS production information system.

A part of our activities was also devoted to the development of custom-designed measuring equipment and the establishment of a development environment for microprocessor applications.

For the needs of the BRACCIA European project the Cardio&BrainSignals 12-channel measurement system was designed to measure ECG, EEG, respiratory effort, blood pressure, skin conductivity, high-resolution temperature and two auxiliary channels (Fig. 5). The system is used in research at the Royal Lancaster Infirmary, the Physics Department at Lancaster University and Ulleval Hospital, University of Oslo.

To fulfil the needs for the development of new electronic devices a development environment was established that will enable the design of

Figure 3: An excerpt from the system for statistical control of the manufacturing line for vacuum-cleaner motors

embedded control and digital signal processing systems, based on the ARM core microprocessors. The programming environment consists of the proprietary LPC2148 ARM processor-based development board, the assembler, the compiler, the debugger, the graphical interface and the FreeRTOS real-time operating system.

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 2006, four one-week courses were organized. These courses were organized in close co-operation with the Information Technologies Knowledge Transfer Center at the Jožef Stefan Institute.

Some outstanding publications in the past three years

1. Dolanc, Gregor, Strmčnik, Stanko. Identification of nonlinear system using a piecewise-linear Hammerstein model. Syst. control. lett.. [Print ed.], 2005, vol. 54, str. 145–158.
2. Hvala, Nadja, Strmčnik, Stanko, Šel, Davorka, Milanič, Srečko, Banko, Blaže. Influence of model validation on proper selection of process models - an industrial case study. Comput. chem. eng.. [Print ed.], 2005, vol. 29, str. 1507–1522.
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, str. 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)

Patent granted

1. Miloš Ružič, Berta Kotar-Jordan, Matej Smrkolj, Samo Gerkšič, Damir Vrančić, Milena Benedik, Mira Gričar: Process for preparing clopidrogel hydrogen sulfate of form I : EP patent no. EP1693375, 2006, Rijswijk, Netherlands, European patent Office.

Organization of conferences, congresses and meetings

1. Modelling and simulation of control systems: continuing education (specialisation) course in Control Technology, Ljubljana, 30 January – 3 February 2006
2. Industrial regulation systems: continuing education (specialisation) course in Control Technology, Ljubljana, 3–7 April 2006
3. Advanced control methods: continuing education (specialisation) course in Control Technology, Ljubljana, 29 May – 2 June 2006
4. Software for process control: continuing education (specialisation) course in Control Technology, Ljubljana, 16–20 October 2006

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.
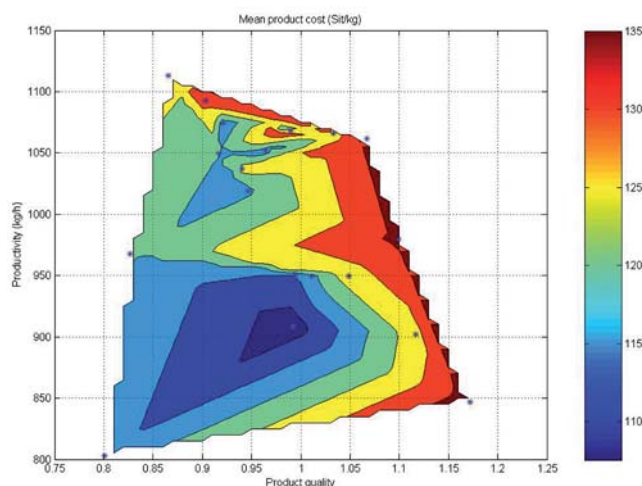

Figure 4: Production model simulation results: Estimation of the production costs in a polymerisation plant

Figure 5: The Cardio&BrainSignals 12-channel measurement system, which enables the measurement of ECG, EEG, respiratory effort, blood pressure, skin conductivity, high-resolution temperature and two auxiliary channels

Jožef Stefan Institute

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In: Control Engineering Practice, Vol. 14, no. 8, pp. 935-948, 2006.

2. Samo Gerkšič, Darko Vrečko, Nadja Hvala
Improving oxygen concentration control in activated sludge process with estimation of respiration and scheduling control
In: Water sci. technol., Vol. 53, no. 4-5, pp. 282-291, 2006.

3. Svein A. Landsverk, Per Kvandal, Trygve Kjelstrup, Uroš Benko, Alan Bernjak, Aneta Stefanovska, Hebe Kvernmo, Knut Arvid Kirkeboen
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4. C. Rosen, Darko Vrečko, K. V. Gernaey, Marie-Noëlle Pons, Ulf Jeppsson
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5. Aljaž Stare, Nadja Hvala, Darko Vrečko
Modeling, identification, and validation of models for predictive ammonia control in a wastewater treatment plant: a case study
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6. Eveline I.P. Volcke, K. V. Gernaey, Darko Vrečko, Ulf Jeppsson, Marinus Cornelis Maria van Loosdrecht, Peter Vanrolleghem
Plant-wide (BSM2) evaluation of reject water treatment with a SHARON-anammox process
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7. Darko Vrečko, K. V. Gernaey, C. Rosen, Ulf Jeppsson
Benchmark simulation model No. 2 in Matlab-Simulink: towards plant-wide WWTP control strategy evaluation
In: Water sci. technol., Vol. 54, no. 8, pp. 65-72, 2006.

8. Darko Vrečko, Nadja Hvala, Aljaž Stare, Olga Burica, Marjeta Stražar, Meta Levstek, Peter Cerar, Sebastjan Podbevšek
Improvement of ammonia removal in activated sludge process with feedforward-feedback aeration controllers
In: Water sci. technol., Vol. 53, no. 4-5, pp. 125-132, 2006.

9. Mina Žele, Darko Vrečko, Đani Juričić
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1. Bojan Musizza, Janko Petrovčič, Dejan Tinta, Jože Tavčar, Gregor Dolanc, Janez Koblar, Đani Juričić
Izvedba sistema za avtomatsko končno kontrolo kakovosti elektromotorjev za sesalnike: Implementation of a system for the automatic end-quality assessment of vacuum-cleaner motors
In: Stroj. vestn., Vol. 52, No. 3, pp. 170-180, 2006.

PUBLISHED CONFERENCE PAPERS
Regular Papers

1. Fernando Aller
Model-based optimization of the production of polyvinyl acetate
In: Proceedings of the 7th International Ph.D. Workshop: Young generation viewpoint: September 25-30, 2006, Hrubá Skála, Chech Republich, Václav Šmídl, ed., Josef Andrýsek, ed., Jan Přikryl, ed., [S. l.], Institute of Information Theory and Automation, 2006, pp. 5-11.

2. Kristjan Ažman, Juš Kocijan
Gaussian process models validation: biotechnological systems case studies
In: 5th MATHMOD: proceedings(Argesim report, no. 30), 5th Vienna Symposium on Mathematical Modeling, February 8-10, 2006, Vienna University of Technology, Inge Troch, ed., Felix Breitenecker, ed., Vienna, Argesim, 2006, pp. 3-1-3-10.

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5. Uroš Benko, Đani Juričić
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9. Vladimir Jovan, Sebastjan Zorzut
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10. Vladimir Jovan, Sebastjan Zorzut, Alenka Žnidaršič
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12. Gregor Kandare
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13. Satja Lumbar, Damir Vrančić
Study on disturbance-rejection magnitude optimum method
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21. Damir Vrančić, Steven L. Smith
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23. Sebastjan Zorzut, Vladimir Jovan, Alenka Žnidaršič
Key performance indicators in plant-wide control
In: ICINCO 2006: proceedings of the third international conference on informatics in control, automation and robotics, Intelligent control systems and optimization, Setúbal, Portugal, August 1-5, 2006, proceedings of the third international conference on informatics in control, automation and robotics, Intelligent control systems and optimization, Setúbal, Portugal, August 1-5, 2006, [Setúbal], INSTICC, cop. 2006, pp. 179-182.

THESES

Ph. D. Theses

1. Dejan Gradišar: Computer-aided modelling for production-task scheduling
2. Dejan Tinta: Fault detection in the mass production of electric motors (Đ. Juričić)

B. Sc. Theses

1. Maja Marcola: Assessing the human orientation of an air-traffic control system (Juš Kocijan)
2. Mitja Rijavec: The setting of a reference temperature profile for a reflow oven (Juš Kocijan)
3. Dean Trojer: Hands-on-experiment framework for automatic control (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. The Control System for the Plasma Cleaning Machine
Primož Eiselt, PlasmaBull GmbH, Lebring, Austria
Dr. Vladimir Jovan

5. 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

6. Data-Driven Modelling for Decision-making Support and Process Monitoring
BI-CZ/05-06/008
Dr. Tatiana Valentine Guy, Institute for Information Theory and Automation, Department of Adaptive Control, Prague, Czech Republic
Asst. Prof. Đani Juričić

7. 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, Hungary
Asst. Prof. Đani Juričić

8. 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

9. Design of PDI Controllers: Interchange of Technology and Experience
BI-PT-04-06-020
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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

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. Stanko Strmčnik

4. Early diagnosis of lung cancer in subjects with occupational asbestosis
Asst. Prof. Đani Juričić

5. Development and optimisation of personal military equipment
Asst. Prof. Đani Juričić

RESEARCH PROGRAM

1. Systems and Control
Prof. Stanko Strmčnik

NEW CONTRACTS

1. Design of a module for automatic tuning of control systems
TKR d.o.o., Godovič
Asst. Prof. Đani Juričić

2. Self-adaptive actuator prototype
Danfoss Trata d.d. Ljubljana
Asst. Prof. Damir Vrančič

VISITORS FROM ABROAD

1. Dr. Carlos Alberto Mendez, Politecnica de Catalunya, Barcelona, Spain, 18 January 2006
2. Asst. Prof. Alexandra Grancharova, Bulgarian Academy of Sciences, Institute of Control and System Research, Sofia, Bulgaria, 2–15 December 2006
3. Prof. L. Felipe Blázquez, Area of Systems Engineering and Control, Dept. Electronic and Electrical Engineering, University of León, León, Spain, 6–13 May 2006
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5. Dr. Muhidin (Dino) Lelić, United Technologies Research Center, East Hartford, USA, 18 December 2006

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19. Bojan Musizza, B. Sc.
20. Boštjan Pregelj, B. Sc.
21. Aljaž Stare, B. Sc.
22. Aleš Svetek, B. Sc.
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24. Sebastjan Zorzut, M. Sc.

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26. Giovanni Godena, B. Sc.
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