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.

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
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.

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

Figure 2: Control of nitrate nitrogen NO$_3$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 wastewater treatment, the development of modules for vibro-acoustic analysis, and the conceptual design of information support for solving partially structured production management processes.

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

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.

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 built 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
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**


**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 Petrovič, Gregor Dolanc, Bojan Mustizza, Dani Juričić, Dejan Tinta, Uroš Benko, Stane Cerne, Janez Grom, Miro Štrubelj)

**Patent granted**


**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
BIBLIOGRAPHY

ORIGINAL ARTICLES

1. Samo Gerkšič, Gregor Dolanc, Damir Vrančič, Juš Kocijan, Stanko Strmčnik, Sašo Božiček, Anna Stathaki, Robert E. King, Mincho B. Hadjievski, Kosta Boshnakov
   Advanced control algorithms embedded in a programmable logic controller

2. Kristjan Ažman, Juš Kocijan, Stariko Strmčnik, Sašo Božiček, Miroslav Stojančič
   Improving oxygen concentration control in activated sludge process with estimation of respiration and scheduling control

3. Svem A. Lundeved, Per Kvaruds, Trygve Kjelstrup, Urot Benko, Alan Bernjak, Aneta Stefanovska, Heve Kervorno, Knut Arvid Kirkeboen
   Human skin microcirculation after brachial plexus block evaluated by wavelet transform of the laser doppler flowmetry signal

4. C. Rosen, Darko Vrečko, K. V. Gernaey, Marie-Noëlle Pons, Ulf Jeppsson
   Implementing ADIM for plant-wide benchmark simulations in Matlab/Simulink

5. Aljaž Star, Nadja Brlja, Darko Vrečko
   Modeling, identification, and validation of models for predictive ammonia control in a wastewater treatment plant: a case study

6. Eveline LP Volke, K. V. Gernaey, Darko Vrečko, Ulf Jeppsson, Mariusz Cornelis Maria van Loosdrecht, Peter Vanrolleghem
   Plant-wide (BSM2) evaluation of reject water treatment with a SHARON/anammox process

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

8. Darko Vrečko, Nadja Brlja, Aljaž Star, Olga Burica, Marjeta Strulj, Petra Lepovšek, Peter Cerar, Sebastian Podbregar
   Improvement of ammonia removal in activated sludge process with feedforward-feedback aeration controllers

9. Mina Zole, Darko Vrečko, Ido Jurčič
   Zaznavanje nepravilnega delovanja sesalnikov: Implementation of a system for the automatic end-quality assessment of vacuum-cleaner motors

REVIEW ARTICLES AND CHAPTERS IN BOOKS

1. Bojan Musić, Janko Petrovič, Dejan Tinta, Jože Tančar, Gregor Dolanc, Janek Klobar, Ido Jurčič
   Izvedba sistema za avtomatsko končno kontrolo kakovosti elektromotorjev za sesalnike: Implementation of a system for the automatic end-quality assessment of vacuum-cleaner motors

PUBLISHED CONFERENCE PAPERS

Regular Papers

1. Fernando Aller
   Model-based optimization of the production of polyvinyl acetate

2. Kristjan Atman, Jari Kocijan
   Gaussian process models validation: biotechnological systems case studies

3. Kristjan Atman, Jari Kocijan
   An application of Gaussian process models for control design

4. Kristjan Atman, Jari Kocijan
   Identified model specification in some areas of research in mathematical modeling

5. Urot Benko, Ido Jurčič
   Use of Gaussian process models in the probabilistic fault diagnosis of a reactor plant

6. Ivan Škrjanc, Thomas Löscher, Dejan Gradišar
   On-line control using the particle swarm optimisation algorithm

Janko Černetič
Some more evidence for justifying human-centred systems

Vladimir Jovan, Sebastian Zuzart
Use of key performance indicators in production management

Vladimir Jovan, Sebastian Zuzart, Alenka Zuzarić
Utilization of key performance indicators in production control

Jožef Stefan Institute
INTERNATIONAL PROJECTS

1. Design of Advanced Controllers for Economic, Robust and Safe Manufacturing
   Performance
   CONNECT
   6. FP
   COOP-CT-2006-031638
   EC, Dr. Constantininos Pantelides, Process Systems Enterprise Limited, London, Great Britain
   Dr. Stanko Strmčnik, Dr. Gregor Dolanc

2. Towards Knowledge - Based Processing Systems
   PRISM
   6. FP
   AST5-CT-2006-050839
   EC, Bruno Pattin, Claire Lallemend, Dassault Aviation, Paris, France
   Prof. Stanko Strmčnik, Dr. Gregor Dolanc

3. Explicit Nonlinear Model Predictive Control based on Gaussian Process Models
   Prof. Alexsandra Grancharova, Institute of Control and System Research, Bulgarian Academy of Sciences, Sofia, Bulgaria
   Prof. Juš Kocijan

4. Data-Driven Modelling for Decision-making Support and Process Monitoring
   B-GR-05/06-0088
   Dr. Tatiana Vancouver, Institute for Information Theory and Automation, Department of Adaptive Control, Prague, Czech Republic
   Asst. Prof. Dani Juričič

5. Analysis, Diagnosis and Control of Distributed Nonlinear Process Systems
   B-GR-06/07-0086
   Sc. Dr. Katalin Haragos, Computer and Automation Research Institute, Hungarian Academy of Sciences, Budapest, Hungary
   Asst. Prof. Dani Juričič

6. Design of PID Controllers: Interchange of Technology and Experience - Second Part
   B-PT-06-07-0085
   Prof. José Paulo de Maura Oliveira, Engineering Department, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal
   Asst. Prof. Dani Juričič

7. Design of PDI Controllers: Interchange of Technology and Experience
   B-PT-04/06-0201
   Asst. Prof. José Paulo de Maura Oliveira, Engineering Department, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal
   Asst. Prof. Dani Juričič

8. Building Virtual Communities for Research and Education in Automation and Control
   BSRK/05/07-0099
   Prof. Mikuláš Huba, Slovak University of Technology in Bratislava, Bratislava, Slovakia
   Asst. Prof. Dani Juričič

R & D GRANTS AND CONTRACTS

1. Design of fault detection and isolation systems with application to quality assessment of electrical motors
   Asst. Prof. Dani Juričič

2. An intelligent system for condition monitoring of rotating machinery
   Asst. Prof. Dani Juričič

3. Optimization of HVAC systems using dynamic models
   Prof. Stanko Strmčnik

4. Early diagnosis of lung cancer in subjects with occupational asbestosis
   Asst. Prof. Dani Juričič

5. Development and optimisation of personal military equipment
   Asst. Prof. Dani Juričič

RESEARCH PROGRAM

1. Systems and Control
   Prof. Stanko Strmčnik

NEW CONTRACTS

1. Design of a module for automatic tuning of control systems
   TRK 351-10-001
   Prof. Dani Juričič

2. Self-adaptive actuator prototype
   Danfoss Trata d.d. Ljubljana
   Asst. Prof. Dani Juričič

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

4. Prof. Dr Alfred C. Snider, University of Vermont, Burlington, USA, 9 November 2006

5. Dr. Muhidin (Dino) Lelić, United Technologies Research Center, East Hartford, USA, 18 December 2006
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