

*The Department of Systems and Control is engaged in research, development, applications and education in various areas of control technology. Its mission is “to bridge the gap between theory and practice”. Hence, the research activities are relatively applied oriented, and the work content closely related to the needs of various companies.*

## Basic and applied research

Research in **fault detection** and isolation has concentrated on three thematic areas. In the area of robust diagnosis the problem of reliable detection in the presence of modelling errors has been studied (Fig. 1). It was shown that the problem reduces to testing statistical hypotheses on a series of nonstationary random variables. Moreover, the same problem has been identified in the context of fault detection, employing the Gaussian process models.

In the second area, an attempt has been made to apply statistical approaches to sensor fault detection in wastewater treatment plants. In order to eschew the laborious, first principles modelling, we made use of process histories enabling the basic method of principle components analysis to be accommodated to deal with nonstationary processes.

The third area of research focused on new methods for diagnosis of rotating machinery. In particular, the problem of revealing mechanical faults by acoustic analysis in the presence of noise from the environment has been addressed.

The research in the area of **analysis and control of complex systems** is split into two sub areas.

In the first, emphasis was given to developing different methods for the modelling and control of non-linear processes. In this context we have investigated the use of Gaussian processes in connection with the local models approach to modelling, as well as in relation to predictive control. We have also worked on the identification of non-linear systems using the piece-wise linear Hammerstein model. The method derived in previous years has been completed.

One part of the activities within this sub area was devoted to improving and upgrading methods for tuning controllers. Emphasis was given to improving disturbance rejection of PI controllers by means of the magnitude optimum method.

Research in the second sub-area was devoted to the modelling and control of waste-water treatment plants, which enabled the EU 5<sup>th</sup> framework project “SMAC – SMARt Control of wastewater systems” to be finished. The aim of this project was to optimise the nitrification process in the wastewater treatment plant by on-line adjustment of the optimal oxygen concentration for air supply. Testing different control strategies on the real plant has shown that feedforward control based on influent ammonia concentration gives more stable effluent quality, together with up to 45% energy saving compared to the usually used constant

*In 2004 dr. Janko Petrovčič, together with two coauthors from INEA company, was awarded a national (Zois) award for technological achievement: “Co-processor for special applications”.*

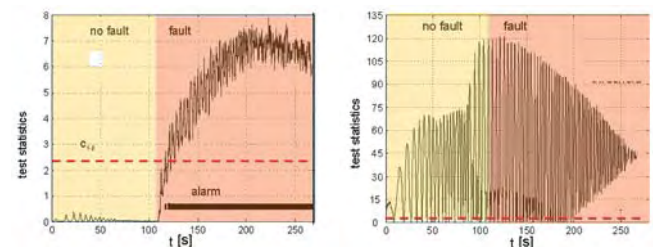
oxygen concentration. On the other hand, more complex control algorithms did not show any additional improvements. The main reason for that was insufficient model quality.

## Research in computer integrated production

was devoted mainly to the area of production management based on Key performance indicators methodology. We have identified a set of essential production key performance indicators and derived a closed loop production management model based on these indicators. This work provides the basis for the design of a decision support system for production management, which is going to be developed in the frame of the 6<sup>th</sup> EU Framework Project PRISM - Towards Knowledge Based Processing Systems.



Head:  
**Prof. Stanislav Strmčnik**



*Figure 1: The response of a robust fault detector (more precisely, the underlying test statistics) to the occurrence of fault in a dynamic system (left). Reliable detection with no false alarms can be observed. However, if modelling errors are ignored (i.e. if the model is fully trusted) the detector can trigger a series of false alarms (right).*

In the area of software (domain) engineering we have continued the research related to automation of the process control SW development process. A prototype of a SW tool was developed, which is able to transfer specifications into program code for PLCs.

Within the area of non-technical aspects of control technology the emphasis was mainly in transferring the methods for human-centred design of socio-technical systems into Slovenian enterprises; with this aim in view, the utility of the system for just-in-time delivery of production parts in the factory Iskraemeco Kranj and the utility of the highway control system around Ljubljana have both been assessed.

## R&D projects

In the frame of long-term cooperation with the INEA company, work on the industrialization of a prototype incorporating advanced

control algorithms in programmable logic controller (ASPECT) has been continued. The emphasis was given to the transfer of the developed SW to new HW and SW platforms, respectively.



Figure 2: Laser based measurements of vibration of suction units in the quality control cell.

Research and development related to fault detection and quality control of vacuum cleaner motors has been continued for the Domel, Železniki company. Based on the results of this research, as well as the results of a prototype developed in the past, an automatic stand for end-quality assessment has been designed, built and installed. The system is able to identify motors with errors in communication, imbalance and improper characteristics (Fig. 2). The system has been installed into the new production line for a new type of suction unit.

For the LEK pharmaceutical company a special program package for tuning PID and cascade controllers has been developed. The derivation of the process model and calculation of process controller parameters is based on original methods, developed as part of the research programme of our group.

In addition to the projects mentioned above, part of our work was devoted to smaller projects, such as pH control in one of the subprocesses in the production of titanium dioxide for the Cinkarna Celje company, preparation of specifications for automatic control of part of a pharmaceutical plant for the Metronik company, and flow

control of monomers in the process of glue production for the Mitol, Sežana company.

### Education activities

Some members of the department give lectures and practical courses at the Faculty of Electrical Engineering, University of Ljubljana, the Polytechnics of Nova Gorica and the "Jožef Stefan" International Postgraduate School. They also act as supervisors of M.Sc and Ph.D. students. Special attention has been dedicated to post-qualification training for engineers from industry. In 2004, four one-week courses were organized in close co-operation with the Information Technologies Knowledge transfer Centre at the Institute.

### Other activities

A substantial part of our work was devoted to the organization, coordination and preparation of R&D projects in the technology network "Process control technology" as part of applying for financing from the European structural funds.

### Some outstanding publications in the past three years

1. Alexandra Grancharova, Tor Arne Johansen, Juš Kocijan. Explicit model predictive control of gas-liquid separation plant via orthogonal search tree partitioning. *Comput. chem. eng.*, 2004, vol. 28, pp. 2481-2491.
2. Đani Juričić, Mina Žele. Robust detection of sensor faults by means of a statistical test. *Automatica (Oxf.)*, 2002, vol. 38, pp. 737-742.
3. Darko Vrečko, Nadja Hvala, Juš Kocijan. Wastewater treatment benchmark: What can be achieved with simple control?. *Water sci. technol.*, 2002, vol. 45, pp. 127-134.

### The most important technological achievements in the past three years

1. A control system for magneto-focused plasma annealer (Gregor Dolanc, Samo Gerškšič)
2. A system for quality control of suction units (Janko Petrovčič, Gregor Dolanc, Bojan Musizza, Đani Juričić, Dejan Tinta, Uroš Benko, Janez Grom, Miro Štrubelj)

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## ORIGINAL ARTICLES

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## PUBLISHED CONFERENCE PAPERS

### Published Invited Conference Paper

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Noise and synchronization on micro and macroscopic scales  
In: Fluctuations and noise in biological, biophysical, and biomedical systems II: 26-28 May 2004, Maspalomas, Gran Canaria, Spain (Proceedings of SPIE, vol. 5467), Derek Abbott, ed., Bellingham (USA), SPIE, cop. 2004, pp. 273-282.

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Viewpoint: September 8-11, 2004 Balatonfüred, Hungary, [S.l., s.n.], 2004, 6 str..
2. Robert Blatnik, Janko Černetič  
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Improving oxygen concentration control in activated sludge process  
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16. Andrej Rakar, Sebastian Zorzut, Vladimir Jovan  
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17. Vladimir Jovan, Stojan Kokošar  
Ak3-1: napredni gradniki za celovit sistem računalniško podprtega vodenja proizvodnje (JSI report, 9095), 2004.
18. Janko Petrovčič, Dani Juričič, Dejan Tinta, Bojan Musizza  
Funkcionalna verifikacija merilnih celic za končno kontrolo sesalnih enot (JSI report, 8920), 2004.
19. Andrej Rakar, Mina Žele, Vladimir Jovan  
Stanje proizvodne informatike doma in v tujini (JSI report, 9076), 2004.
20. Darko Vrečko, Nadja Hvala, Vladimir Jovan, Stanko Strmčnik  
Študija možnosti glajenja porabe pare pri proizvodnji TiO<sub>2</sub> v Cinkarni Celje (JSI report, 9067), 2004.
21. Sebastjan Zorzut, Vladimir Jovan  
Uravnoteženi sistem kazalnikov za vodenje proizvodnje (JSI report, 8941), 2004.

## PATENT

### Patent granted

1. Patent no: 21381  
Spark detector and sparking intensity analyzer for motors with commutator  
Janko Petrovčič, Dani Juričič, Dejan Tinta  
Ljubljana: Urad RS za intelektualno lastnino

## THESES

### B. Sc. Theses

1. Gregor Malik: Bar code implementation in Gostol-Gopani company (Juš Kocijan)
2. Andreja Marušič: The assessment of antropocentricity of batch neutralisation process control with KOMPASS method (Juš Kocijan)

### M. Sc. Theses

1. Kristjan Ažman: Gaussian process model identification of dynamical systems with incorporated linear models (Juš Kocijan)
2. Bojan Likar: Nonlinear model-predictive control based on Gaussian process models (Juš Kocijan)
3. Dejan Tinta: Fault detection in systems with complex dynamics: an example of quality assessment of vacuum cleaner motors (Aneta Stefanovska)
4. Sebastjan Zorzut: Design of the balanced scorecard system for the production management support (Rihard Karba)

### Ph. D. Theses

1. Boštjan Hauptman: Production scheduling in process industry (Rihard Karba, Stanko Strmčnik)
2. Gregor Kandare: Računalniško podprto načrtovanje programske opreme za postopkovno vodenje s programirljivimi logičnimi krmilniki (Rihard Karba)

## MESS SUPPORTED RESEARCH AND DEVELOPMENT GRANTS AND CONTRACTS

1. Industrialization of advanced control algorithms for PLC  
Prof. Stanislav Strmčnik, Dr. Samo Gerksič
2. Development of fault detection and isolation methods with application to the end-quality assessment in the production of electrical motors  
Asst. Prof. Dani Juričič
3. Development and optimisation of personal military equipment  
Asst. Prof. Dani Juričič

### Research program

1. Systems and control  
Prof. Stanislav Strmčnik

## INTERNATIONAL PROJECTS

1. Towards Knowledge - Based Processing Systems  
PRISM  
6. FP  
MRTN-CT-2004-512233  
EC; Imperial College of Science Technology and Medicine, London, Great Britain  
Dr. Mina Žele
2. Smart Control of Wastewater Systems  
SMAC  
5. FP  
EVK1-CT-2000-00056  
EC; Marinus K. Nielsen, Henrik A. Thomsen, Krüger A/S, Søborg, Denmark  
Dr. Nadja Hvala
3. Multi-Agent Control: Probabilistic Reasoning, Optimal Coordination, Stability Analysis and Controller Design for Intelligent Hybrid System  
MAC  
5. FP  
HPRN-CT-1999-00107  
EC; Dr. Roderick Murray-Smith, University of Glasgow, Department of Computing Science, Glasgow, Great Britain  
Prof. Juš Kocijan
4. Control and Supervision of Technological Processes by using Mixture Modelling  
BI-CZ/03-04-26  
Dr. Tatiana Guy, Institute for Information Theory and Automation, Department of Adaptive Control, Prag, Czech Republic  
Dr. Andrej Rakar
5. Optimal Control of Biological Wastewater Treatment Plants  
SLO-ITA 4B/2002-2005, BI-IT/02-05-022  
Prof. Stefano Marsili-Libeli, University of Florence, Department of Systems and Computers, Firenze, Italy  
Dr. Nadja Hvala
6. Advanced Modelling Techniques for Distributed Parameter Systems with Application to Fault Diagnosis  
BI-MK/04-05-014  
Prof. Georgi Dimirovski, Faculty of Electrical Engineering, Skopje, Institute of Automation & Systems Engng., Skopje, Macedonia  
Asst. Prof. Dani Juričič
7. Design of PDI controllers: Interchange of Technology and Experience  
BI-PT-04-06-020  
Prof. José Paulo B. De Moura Oliveira, Engineering Department, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal  
Dr. Damir Vrančič

## NEW CONTRACTS SIGNED

1. Development of fault detection and isolation methods with application to the end-quality assessment in the production of electrical motors  
Domel, d. d., Železniki  
Dr. Janko Petrovčič
2. Development of programme package for tuning, optimisation and documentation of control loops  
Lek, d. d., Ljubljana  
Asst. Prof. Damir Vrančič

3. Development of control loop programme modules  
Lek, d. d., Ljubljana  
Asst. Prof. Damir Vrančič
4. Project "Sinteza IV": Functional Design Specification (FDS)  
Ljubljana  
Giovanni Godena
5. Design and implementation of control and supervision system for hydraulic testing line HWS 135  
DANFOSS TRATA, d. d., Ljubljana  
Dr. Gregor Dolanc
6. Construction of an automatic stand for end-quality assessment of electromotors for vacuum cleaners  
Domel, d. d., Železniki  
Dr. Janko Petrovčič
7. Project »Pedagog«  
Politehnika Nova Gorica  
Asst. Prof. Damir Vrančič

## VISITORS FROM ABROAD

1. Dr. Roderick Murray-Smith, University of Glasgow, Great Britain and Hamilton Institute, NUIM, Ireland, 23. - 27. 2. 2004
2. Marit Jordet Langhammer, Norwegian University of Science and Technology, Trondheim, Norway, 14. 6. - 23. 7. 2004
3. Steve Jones, Seiji Oguro, Peter Mischitz, Mitsubishi Electric Europe, Ratingen, Germany, 22. 7. 2004
4. Dr. Miroslav Karny, Czech Academy of Sciences, Prague, Czech Republic, 24. 6. 2004
5. Dr. Gabor Szederkenyi, Dr. Katalin M. Hangos, Dr. Attila Magyar, Hungarian Academy of Sciences, Budapest, Hungary, 24. 6. 2004
6. Prof. Dr. Mile Stankovski, Prof. Dr. Tanja Kolmiševska-Gugulovska, Elektrotehnički fakultet, Skopje, Macedonia, 20.-28. 11. 2004

## ORGANIZATION OF CONFERENCES AND MEETINGS

1. Modelling and simulation of control systems: continuing education (specialisation) course in Control Technology, Ljubljana, February 9-13, 2004
2. Industrial regulation systems: continuing education (specialisation) course in Control Technology, Ljubljana, April 5-9, 2004
3. Advanced control methods: continuing education (specialisation) course in Control Technology, Ljubljana, May 31-June 4, 2004

4. Software for process control: continuing education (specialisation) course in Control Technology, Ljubljana, October 11-15, 2004

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