Human Capital and Mobility Network in

CHEMICAL PROCESS CONTROL

Contract no. ERB-CHRX-CT94-0672

Online Mobility Newsletter

edited by
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Porto, Portugal
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Sept. 1996

CONTENTS

Editorial Note

The Network in Chemical Process Control represents a joint effort of thirteen European Departments, with two main stated objectives -

1. To provide extensive training for young postdoctoral workers in this important European industrial area,

and

2. To give the members of the research community in chemical process control the opportunity to develop or reinforce collaborations on topics grouped in three main themes - (i) Modelling and Identification of Chemical Plants; (ii) Monitoring and Control of Non-linear Chemical Processes; and (iii) Tools for Controllability Analysis and Control Strategy Decisions.

In the London Meeting, of September 15-16 1995, The Group decided for the publication of this Newsletter, seen as an effective way to keep Researchers in the area, belonging or not belonging to the Network, informed about our activity and efforts of cooperation.

The job for the Editors is essentially that of compiling in appropriate form for publication the information which the different partners may decide to provide.

The Electronic Mail communications system, the capacity of GETting files through FTP and the WorldWideWeb represent major tools for dissemination of information. We shall keep files of an 'Online Mobility Newsletter' in Word and Word Perfect formats, in a FTP ANONYMOUS location. It will be possible to get them with the FTP tool. This Newsletter will also be available in the WWW system. From this page, it will be possible to get into the different individual pages of Researchers, of Departments, of Universities, to accede abstracts of publications or full publications, you name it...

Please, do contact us by E-Mail. We look forward to hearing comments and suggestions from you and to receiving news for publication.

Porto, January 1996,

The Editors

1. GENERAL INFORMATION

1.1.How to get Mobility Newsletter I

This NEWSLETTER is available in any of the following forms -

a) **Internet WWW**
An hypertext document can be viewed with a WWW browser using the following URL
http://www.deb.uminho.pt/hcm/nlett.htm

b) **Internet FTP**
Binary newsletter files are available at the host address
ftp://adamastor.ci.uminho.pt/publico/hcm/ with login "Anonymous" and password "guest".

cpcnl1ww.doc	WinWord6 file
cpcnl1ww.zip	compressed WinWord6 file, for faster transfer
cpcnl1wp.doc	Word Perfect file
cpcnl1wp.zip	Compressed Word Perfect file, for faster transfer
cpcnl1ps.ps	Postscript file for UNIX systems
cpcnl1ps.zip	Compressed Postscript file for UNIX systems, for faster transfer

Please note that FTP is available directly from the WWW link, mentioned above.

c) **Paper version**
Anyone interested in receiving a paper version by ‘snail’ mail, does need only to put the request to the Editors, by e-mail, stating clearly name, organization and organization address.

1.2.Network Participants

The following Research Groups and Laboratories are involved in the network

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1.3.Network internal organization

The activity of the network has been organized in six subgroups, corresponding to the areas of research which fitted best with the envisaged activities of cooperation.

A coordinator has been dignated for each of such subgroups -

SB1 - ***Modelling Tools and Computer-Aided Design*** (coordinator Wolfgang Marquardt)

SB2 - ***Identification for Control*** (Dominique Bonvin)

SB3 - ***Nonlinear Estimation and Control*** (Pierre Rouchon)

SB4 - ***Real-time Optimisation*** (John Perkins)

SB5 - ***Process Monitoring and Data Interpretation*** (Julian Morris)

SB6 - ***Controllability Analysis and Plantwide Control*** (Diane B. Rossiter)

2. INFORMATION ON MOBILITY

- On the 1st of February, 1996, Dr. Bernhard Dahm (from Stuttgart) started a period of 9 months of postdoc work in Porto, under the auspices of the network. He will work on the development of AI methodologies for state estimation and control of biorectors.
- In 1995, from September 29 to October 10, Achim Helbig (RWTH) visited Lausanne and worked on the subject: 'Modelling, on-line estimation and optimization of batch chemical reactors'.
- In 1995, from 2-6 October, Benjamin Bonnet (PhD student) of CESAME visited Exeter to become familiar with experimental work carried out at Exeter on the modelling and control of a pilot-plant scale activated sludge process.
- In 1995, from July 10 to September 12, Michael Amrhein (from EPFL) visited Newcastle and worked on the topic 'Hybrid modelling of chemical and biochemical batch processes'. On the same topic, Dr. Libei Chen (Newcastle) is to visit Lausanne, from December 5, 1995, till January 15, 1996.
- In 1995, September, by occasion of the ECC95 Conference in Rome, a Meeting of Theme 6 took place to discuss future activities of Theme members - D.B. Rossiter (Exeter), Jorgensen (DTH), Haggblom (Abo), Hovd (NTH), Perkins (ICSTM), Skogestad (NTH), Waller (Abo), Walsh (ICSTM)). Also the meeting was attended by Dr Elling Jacbsen, STH, Sweden and Prof. Claudio Scali, Pisa both are interested in becoming involved in the future TMR network proposal.
- In 1995, The Centre for Process Systems Engineering (IC London) has welcomed two visitors under the auspices of the network and some of their Members were Visitors to other Institutions:
    - Jean-Christophe Culioli (École des Mines) spent about 6 weeks in the Centre between March and June 1995. During this time he worked with many people in the Centre and exchanged papers and ideas.
    - Cristiano Cortonesi (Pisa), a student of Claudio Scali's, worked in the Centre for two months, with Steve Walsh, on using MILP techniques for control structure selection and made a modest contribution to work in this area. He gave a seminar on the work back in Pisa.
    - Three members of the Centre, Steve Walsh, Eva Sorensen and Jezri Mohideen attended the meeting in Stuttgart on distillation control. Jezri presented a paper there.
- In 1994/95 Mike Papzoglou and George Murikas from Thessaloniki spent 9 months in Newcastle
- In 1994, December, Dr Diane B. Rossiter visited Dr Pierre Rouchon at Ecole de Mine, Paris.

3. JOINT PUBLICATIONS

Y. Cao, D. Biss (Exeter) and J.D. Perkins (ICSTM), Special issue of *Computers and Chemical Engineering*, Vol. 20, No. 4, April 1996.

Y. Cao and D. Biss, An extension of singular value analysis for assessing manipulated variable constraints. *Journal of Process Control*, Vol. 6, No. 1, 37-48, 1996.

Lefevre, L., Dochain, D., Feyo de Azevedo, S. Some properties of the orthogonal collocation method used for approximating distributed parameter process models. To be presented at the *15th Benelux Meeting on Systems and Control*, 6-8 March, Mierlo, The Netherlands, 1996.

Waldraff, W., Dochain, D. On the use of observability measures for sensor location in fixed bed reactors. To be presented at the *15th Benelux Meeting on Systems and Control*, 6-8 March, Mierlo, The Netherlands, 1996.

Christiansen, A.C., Jacobsen, E.W., Perkins, J.D., Skogestad. On the dynamics of batch distillation: a study of parametric sensitivity in ideal binary columns. *AIChE Annual Meeting*, Miami Beach, USA, Nov., Paper 184d, 1995.

Chen, L., Amrhein, M., Morris, J., Bonvin, D. Modelling and state estimation of bioprocesses: the use of neural networks and mass balance equations (in preparation)

4. PAST EVENTS

UKACC- Control'96 (Exeter), 2-5 September 1996
Invited Sessions Programme

Organizer: Dr Diane Rossiter (nee Biss), Loughborough University, UK

Advances in Process Control I Program: Control Structure Selection in Control Design Session 3C
Tuesday, 3 September 14:00-15:40
Chair: Dr D Rossiter, Co-chair: Dr S P Walsh

1. *Selection of feedback variables for implementing optimizing control schemes*
K Havre, J Morud and S Skogestad
Department of Chemical Engineering, NTH, N-7034 Trondheim, Norway

2. *Input screening techniques for disturbance rejection*
Y Cao and D.Rossiter
School of Engineering, University of Exeter, Exeter EX4 4QF, UK Loughborough University, Loughborough LE11 3TU

3. *optimisation and process controllability analysis*
S Chenery and S P Walsh
Centre for Process Systems Engineering, Imperial College of Science and Technology, London SW7 2BY, UK

4. *Control structure selection for heat integrated distillation column*
J E Hansen, J Heath (ICSTM) and S B Jorgensen
Department of Chemical Engineering, DTH, Denmark

5. *On the controllability of svd control structures*
M Sagfors and K Waller
Process Control Laboratory, Abo Akademi University, Turku, Finland

Advances in Process Control II Program Performance Monitoring and Identification for Control Session 6C

Wednesday, 4 September 11:00-12:40
Chair: Professor S Skogestad, Co-chair: Dr K E Haggblom

1. *Multimodel identification for control of an ill-conditioned distillation column*
K E Haggblom and J M Boling
Process Control Laboratory, Abo Akademi University, Turku, Finland

2. *System identification via genetic programming*
C Bancroft, M J Willis and M T Tham
Department of Chemical Engineering, University of Newcastle Upon Tyne, UK

3. *A framework for process design and control*
M J Mohideen, J D Perkins and E N Pistokopoulos
Centre for Process Systems Engineering, Imperial College of Science and Technology, London SW7 2BY, UK

4. *Nonlinear performance monitoring*
J Zhang, E B Martin and A J Morris
Department of Chemical Engineering, University of Newcastle Upon Tyne, UK

5. *Effect of RHP zeros and poles on performance in multivariable systems*
K Havre, and S Skogestad
Department of Chemical Engineering, NTH, N-7034 Trondheim, Norway

Advances in Process Control III: Modelling and Control of Chemical Processes Session 8C Thursday, 5 September 11:00-12:40
Chair: Professor S Feyo de Azevedo, Co-chair: Professor C Scali

1. *Simulation and control of a multiple effect evaporator in sugar production*
K M Neilsen, T S Pedersen and J F D Neilsen
Department of Control Engineering, Aalborg University, DK 9220 Aalborg, Denmark

2. *Analysis and nonlinear model predictive control of the Chylla-Haase benchmark problem*
A Helbig, O Abel, A M'hamdi and W Marquandt
Lehrstuhl fur Prozesstechnik, RWTH Aachen, 52056 Aachen, Germany

3. *Nonlinear H-infinity control of a high purity distillation column*
A Rehm and F Allgower
Institut fur Systemdynamik und Regelungstechnik, Universitat Stuttgart, D-70550 Stuttgart, Germany

4. *Adaptive linearising control of bioreactors*
E C Ferreira and S Feyo de Azevedo
Departmento de Engenharia Química, Universidade do Porto, 4099 Porto Codex, Portugal

5. *Tuning of decentralized multiloop controllers by a relay technique advantages in application to chemical processes*
C Scali and D Semino
Department of Chemical Engineering, University of Pisa, 2-56126 Pisa, Italy

One-day workshop on Nonlinear Estimation and Control (Paris)

The workshop took place, on Friday 19 April, in Paris, at Ecole des Mines organized by Dr. Pierre Rouchon.

Abstracts

On the Stability of a Quasi-Infinite Horizon Nonlinear Model Predictive Control Scheme
H. Chen, F. Allgower (Institut fur Systemdynamik und Regelungstechnik, Universitat Stuttgart)

In this talk we present a novel quasi-infinite horizon nonlinear model predictive control scheme for stable and unstable constrained plants for which we can proof asymptotic stability.
Unlike for other known nonlinear model predictive control schemes, for which stability can also be proven, only a finite prediction and finite control horizon have to be considered. The objective function includes a terminal state penalty term and a terminal inequality state constraint where the terminal state penalty is chosen as the positive definite solution an appropriate Lyapunov equation.
Like other known stability results for nonlinear predictive control schemes, the given stability conditions are only sufficient and unfortunately rather conservative. The approach will be illustrated with several process control examples.

Nonlinear worst-case output feedback design: an illustrative example
A. Rapaport (Imperial College, London).

A simple pursuit in the plane, whose solution is already known under perfect information, is investigated under the framework of an incomplete information structure where the Certainty Equivalence Principle cannot be applied. The nonlinear theory, proposed by Bernhard for partial information differential games, is stretched here for free end-time problems.

Nonlinear Dynamics and Control of a Fixed Bed Reactor
Bodil Recke and Sten Bay Joergensen (Department of Chemical Engineering, Technical University of Denmark, Lyngby).

This presentation will describe the dynamic behaviour which arise when recycle is applied to a fixed bed reactor. The types of recycle which are investigated are: recycle of mass (unconverted reactant), recycle of energy (heat exchange between cold inlet and hot outlet gas), or a combination of the two. The results are the multiple steady states can occur, when energy recycle is applied. Furthermore periodic solutions can exist with all the types of recycle. The dynamic behaviour is described in form of bifurcation diagrams. Control aspects are brefly described.

Simple global nonlinear observers for polymerization reactors
D. Guillaume, P. Rouchon, J. Rudolph (Ecole des Mines de Paris, Centre Automatique et Systèmes).

Using temperature and density measures, we propose nonlinear global exponential observers for the three compositions (monomer, initiator and solvent) in the reactor. Such observers are based on the structure of the system and thus can be used for a large class of polymerization reactors, such as the ones considered by Gauthier and coworkers in a recent paper.

Local "tracking observer" for flat chemical reactors
J. Rudolph, M. Fliess (CAS and ISR, University of Stuttgart and Laboratoire des signaux et systemes, CNRS, Supelec).

Flatness allows to change the operating regime along trajectories chosen off-line. Linearization along such known trajectories allows to freely assign locally exponentially stable observer error dynamics by using a "gain scheduling" like technique.

Robustness of MPC-Based Schemes for Constrained Control of Nonlinear Systems
V. Nevistic, M. Morari (Automatic Control Laboratory, ETH Zurich).

An efficient method for the robustness analysis of model predictive control (MPC) based techniques for constrained nonlinear control is proposed. Performance properties of nonlinear MPC (NLMPC) and MPC with feedback linearization (FL) are measured in terms of an induced norm. dynamical optimization problem with a newly developed power algorithm. The efficiency of the proposed method is demonstrated on two test plants, where the robustness properties of MPC+FL and NLMPC are compared.

One-day workshop on Plantwide Control and Controllability (Lyngby)

The workshop took place, on 20 May 1996 in Lyngby.

Each member of the theme was represented. However, attendance was not restricted to members of the Network so Elling Jacobsen (KTH, Sweden) and Morten Hovd (Fantoft Prosess, Norway) were invited. Eight presentations were given over the day on a variety of topics ranging from the effect of recycles on the plant zero dynamics (presented by Elling Jacobsen) to issues in control structure selection (presented by Professor Sigurd Skogestad). The attendants also had the opportunity to see the energy-integrated distillation column in the pilot plant at DTH. The day concluded with a discussion on the theme's contribution to the proposal for the Teaching and Mobility of Researchers chaired by Dr Walsh. This proposal incorporates new members namely, Dr Hovd, Fantoft Prosess (Norway), Professor Scali, Pisa University (Italy) and Dr Jacobsen, Royal Institute of Technology (Sweden).

5. FORTHCOMING EVENTS

2nd general meeting of the Network in Chemical Process Control (Porto)
The 2nd general meeting of the Network in Chemical Process Control will take place in **Porto**, Portugal, on the **27**th (Friday) and **28**th (Saturday) of **September**, 1996.
Friday morning will be dedicated to discussion of the work developed in each subgroup. This will be coordinated by each subgroup leader. On Friday afternoon a poster session, including a poster preview will be organized. Saturday morning will be dedicated to coordination and management meetings.
Full details with a request for registration will be forwarded soon to the network participants.

6. OTHER ACTIVITY

Work is in progress of preparation for TMR proposal for 1996 submission.

7. SPECIAL TOPICS

- From Julian Morris, we have received in January 24 (1996) the following call for cooperation -

We have a lot of work going on with the paper industries. We would be interested in working with colleagues in this area. Our links are with Argo Wiggins, Calladonian, BPB, KNP Fine Paper (Netherlands), A Swedish company, Voit, SKF Condition Monitoring on paper plant bearings, etc.

- From Dominique Bonvin, we have received the following remark -

It has been our experience that there is a high demand for mobility exchanges of short duration. We personally question the real value of stays under, let us say, 2 months. Comments welcome.

8. ANNUAL PROGRESS REPORT

Reporting Period :1 November 1994 - 31 October 1995

Description of the progress of the network

Introduction

As mentioned in the workprogramme, "The objective of the project is (i) to provide extensive training for young postdoctoral workers in this important European industrial area and (ii) to give the members of the research community in chemical process control the opportunity to develop or reinforce collaborations. This should be achieved via Periodical meetings and via exchange of post-doc researchers (or eventually Ph.D. students) working on common research projects, including at least two laboratories in the network."

The first general meeting in Louvain-la-Neuve in November 1994 has been followed the following two objectives :

(i) to allow each partner to present his research activities with a particular emphasis on the possible collaborations within the network;

(ii) to take the practical decisions in order to have the most efficient network.

With that objective in mind, it has been decided to identify 6 topics for which the theme leaders are responsible to favour the exchanges, in particular via the organisation of specific meetings.

Themes	Leader
Modelling tools and Computer-Aided Design	Wolfgang Marquardt (Aachen)
Identification for control	Dominique Bonvin (Lausanne)
Nonlinear estimation and control techniques	Pierre Rouchon (Paris)
Real-time optimisation	John Perkins (London)
Process monitoring and data interpretation	Julian Morris (Newcastle)
Controllability analysis	Diane Bliss (Exeter)

Activities

Meetings

Over the period 1 November 1994 - 31 October 1995, 3 specific meetings have been organized with the objectives to gather mainly young researchers from the different institutions involved in the network and to give the opportunity to present and discuss their research works:

Theme	Location, Date	Number of Participants
Modelling and Control of Distillation Columns	Stuttgart (Germany) 27-28 July	25
Modelling Tools	Aachen (Germany), 11 August	7
Controllability & Plantwide Control	Rome (Italy), 7 September	10

A second general meeting has taken place in London on 14-15 September. The largest part of the meeting has been dedicated to scientific discussion and interaction via oral sessions for each of 6 themes have been organized with several presentations of scientific results, particularly by young researchers (Ph.D. students and post-doc researchers), and a poster session. At this scientifically intensive meeting, the 60 present researchers have had the opportunity to discuss about the different aspects of the recent developments and scientific results in chemical process control particularly in Europe, as well as their laboratory and industrial applications.

Having in mind that the first year of the project includes a starting phase necessary to initiate efficient collaborations and interactions between the different laboratories, one of the concern of the participants was to introduce some new actions in order to further improve the working of the network. Beside the increase of interactions, exchanges and specific meetings in the second year, it has also ben decided that a Newsletter will regularly (every 3 or 4 months) be distributed by e-mail to all members of the network. The Newsletter will contain the list of all relevant publications of each group over the last period, as well as announcements and reports of network meetings. The management of the Newsletter will be in the hand of a young researcher of Porto.

Exchanges of Young Researchers

The exchanges of young researchers plays a central part in the network. These are summarized in Table 1 for the period 1 November 1994 - 31 October 1995, with the duration of stay, the name of the young researcher involved, and the scientific publications, if relevant.

Table 1: Exchanges between the different institutions for the period November 1994-October 1995 (i.p. = in preparation)

Partner #1 (sending)	Partner #2 (receiving)	Type of exchanges (young researcher)	Results
Stuttgart	Louvain-la-Neuve	6 month post-doc (W. Waldraff)	communication
Stuttgart	Paris	5 month post-doc (J. Rudolph)	
Paris	London	5 months' stay (J.C. Culioli)	
Louvain-la-Neuve	Exeter	1 week stay (B. Bonnet)	
Louvain-la-Neuve	Porto	(L. Lefevre)	communication
Lausanne	Newcastle	2 months' stay (M. Armhein)	paper (i.p.)
Aachen	Lausanne	2 weeks' stay (A. Helbig)	
Aachen	Lyngby	2 weeks' stay (D. Mueller)	
Aachen	Lyngby	1 week's stay (B. Lohmann)	
Thessaloniki	Newcastle	6 months' stay (G. Mouricas, M. Papazogiou)	
Trondheim	Aachen	1 month's stay (A. Christiansen)	
Trondheim	Aachen	2 weeks' stay (H. Moe)	
Aachen	Trondheim	2 weeks' stay (J. Blum)	
Aachen	Trondheim	1 week's stay (B. Lohmann)	

Conclusions

The first year includes a starting phase for the network. The fact that the specific meetings and most of the exchanges of researchers have taken place in the second half of the period is an indicator of this situation. The network tends now to its stationary phase: this would imply an increasing number of specific meetings and exchanges of researchers for the second year. Note also that it is difficult to expect a large number of (already available) publications within one year from the beginning of the network : here again the number of publications is expected to increase.

Factual Information

(see Annexes B of each partner)

List of joint publications

Lefevre L., D. Dochain and S. Feyo de Azevedo (1996). Some properties of the orthogonal collocation method used for approximating distributed parameter process models. To be presented at the *Benelux Meeting on Systems and Control*, 6-8 March, Mierlo, The Netherlands.

Waldraff W. and D. Dochain (1996). On the use of observability measures for sensor location in fixed bed reactors. To be presented at the *Benelux Meeting on Systems and Control*, 6-8 March, Mierlo, The Netherlands.

Christiansen A.C., E.W. Jacobsen, J.D. Perkins and S. Skogestad (1995). On the dynamics of batch distillation : a study of parametric sensitivity in ideal binary columns. *AIChE Annual Meeting*, Miami Beach, USA, November, Paper 184d.

Chen L., M. Armhein M., J. Morris and D. Bonvin (1996). Modelling and state estimation of bioprocesses : the use of neural networks and mass balance equations. *In preparation.*