



Human Capital and Mobility Network in CHEMICAL PROCESS CONTROL

Contract no. ERB-CHRX-CT94-0672



Online Mobility Newsletter

edited by

S. FEYO DE AZEVEDO and E.C. FERREIRA

UNIVERSITY OF PORTO - FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

Porto, Portugal

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CHEMICAL PROCESS CONTROL

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Network Coordinator

Denis Dochain

CESAME, Universite Catholique de Louvain
CESAME, Batiment Euler, Avenue Georges Lemaitre 4-6
B-1348 Louvain-la-Neuve, Belgium
(dochain@auto.ucl.ac.be)

Newsletter Editors

Sebastiao Feyo de Azevedo

Departamento de Engenharia Quimica, Faculdade de Engenharia
Rua dos Bragas, 4099 Porto Codex, Portugal
(sfeyo@fe.up.pt)

and

Eugenio Ferreira

Departamento de Engenharia Biológica, Universidade do Minho
Campus de Gualtar, 4710 Braga, Portugal
(eugenio@deb.uminho.pt)

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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

1. CESAME, Universite Catholique de Louvain, Louvain-la-Neuve, Belgium

Coordinator - Prof. Denis Dochain (dochain@auto.ucl.ac.be)

Address - CESAME, Batiment Euler, Avenue Georges Lemaitre 4-6

B-1348 Louvain-la-Neuve, Belgium

Telephone: +32.10.472378, *Fax* - 32.10.472180

2. Process Control Laboratory, Abo Akademi, Finland

Coordinator - Prof. Kurt Waller (wallerk@finabo.abo.fi)

Address -SF-20500, Abo, Finland

3. Institutet for Kemiteknik, Danmarks Tekniske Hojskole, Lyngby, Denmark

Coordinator - Prof. Sten Bay Jorgensen (sbj@home.kt.dth.dk)

Address -Building 229, 2800 Lingby, Denmark

4. Centre d'Automatique et de Systemes, Ecole des Mines, Paris, France

Coordinator - Prof. Pierre Rouchon (rouchon@cas.ensmp.fr)

Address -60, Bd. Saint-Michel, 75272 Paris Cedex, France

Fax: 33.1.43.54.18.93

5. Lehrstuhl fuer Prozesstechnik, Rheinisch-Westfaelische Technische Hochschule Aachen, Germany

Coordinator - Prof. Dr.-Ing. Wolfgang Marquardt (maq@lfpt.rwth-aachen.de)

Contact Person - Dipl.-Ing. Achim Helbig (ahe@lfpt.rwth-aachen.de)

Other participants -

Dipl.-Ing. Olaf Abel (oab@lfpt.rwth-aachen.de)

Dipl.-Ing. Joachim Blum (jbl@lfpt.rwth-aachen.de)

Dipl.-Ing. Bernd Lohmann (loh@lfpt.rwth-aachen.de)

Dipl.-Ing. Dirk Mueller (dmu@lfpt.rwth-aachen.de)

Address - Lehrstuhl fuer Prozesstechnik RWTH Aachen, Turmstrasse 46

D-52056 Aachen, Germany

Telephone: +49-241-806712, *Fax:* +49-241-8888-326

6. Institut fur Systemdynamik and Regelungstechnik, Universitat Stuttgart, Germany

Coordinator - Prof. E. Gilles

Contact Person - Prof. Frank Allgower (ali@isr.uni-stuttgart.d400.de)

Address -Institut fur Systemdynamik und Regelungstechnik Universitat Stuttgart

Pfaffenwaldring 9 D-70550 Stuttgart, Germany

7. Center for Systems and Control Engineering, School of Engineering, University of Exeter, Great-Britain

Coordinator - Prof. David Owens (D.H.Owens@exeter.ac.uk)

Other participants - Notker Amann (N.Amann@exeter.ac.uk)

Address - Centre for Systems and Control Engineering - University of Exeter

North Park Road, Exeter EX4 4QF, United Kingdom

Telephone: 44.1392.263658/263685, *Fax:* 44.1392.217965

Contact Person - Dr Diane B. Rossiter (d.biss@lboro.ac.uk)

Address - Plant Engineering Group, Department of Chemical Engineering,

Loughborough University, Ashby Road, Loughborough LE11 3TU, UK

Telephone: 44.1509.222.507 *Fax:* 44.1509.233.923

8. Department of Chemical Engineering, University, of Newcastle upon Tyne, Great-Britain

Coordinator - Prof. Julian Morris (Julian.Morris@newcastle.ac.uk)

Other participants - Dr Elaine Martin (E.B.Martin@newcastle.ac.uk)

Address -Department of Chemical and Process Engineering

Merz Court - The University Newcastle upon Tyne NE1 7RU, United Kingdom

Telephone: 44.91.222.7342, *Fax* - 44.91.261.1182

9. Centre for Process Engineering, Imperial College, London, Great Britain

Coordinator - Prof. John. Perkins (umeca10@ps.imperial.ac.uk)

Contact Person - Dr. Steve Walsh (s.p.walsh@ic.ac.uk)

Address -Centre for Process Systems Engineering, Imperial College of Science

Prince Consort Road, London SW7 2BY, United Kingdom

Telephone: 00.44.171.594.6604, *Fax*: 00.44.171.594.6606

10. Department of Chemical Engineering, Aristotle, University of Thessaloniki, Greece

Coordinator - Prof. Costas Kiparissides (cypress@filippos.techpath.gr)

Address -Department of Chemical Engineering, Chemical Process Engineering Research Inst.

Laboratory of Polymer Reaction Engineering

P.O. BOX 472, 540 06, Thessaloniki

11. Process Control Group, Chemical Engineering, Norwegian University of Science and Technology, Trondheim, Norway.

Coordinator - Prof. Sigurd Skogestad (skoge@kjemi.unit.no)

Address -Department of Chemical Engineering, Norwegian University of Science and Technology, Trondheim, NTH, N-7034 Trondheim. Norway

Telephone: 47.73.59.41.54, *Fax*: 47.73.59.4080 or 1410

12. Departamento de Engenharia Quimica, Universidade do Porto, Portugal

Coordinator - Prof. Sebastiao Feyo de Azevedo (sfeyo@fe.up.pt)

Other participants -

Dr. Eugenio Ferreira (eugenio@ci.uminho.pt)

Mr. Nuno Faria (usfanf@fe.up.pt)

Address -Departamento de Engenharia Quimica, Faculdade de Engenharia

Rua dos Bragas, 4099 Porto Codex, Portugal

Telephone: 351.2.204.1694, *Fax*: 351.2.200.08.08

13. Institut d'Automatique - Ecole Polytechnique Federale de Lausanne, Switzerland

Coordinator - Prof. Dominique Bonvin (bonvin@ia.epfl.ch)

Address - Institut d'Automatique, Ecole Polytechnique Federale de Lausanne

CH-1015 Lausanne, Switzerland

Telephone: 41.21.693.38.43, *Fax*: 41.21.693.25.74

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 designated 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 bioreactors.
- 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 Jacobsen, 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.

Waldruff, 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 für Prozesstechnik, RWTH Aachen, 52056 Aachen, Germany

3. *Nonlinear H-infinity control of a high purity distillation column*

A Rehm and F Allgower

Institut für Systemdynamik und Regelungstechnik, Universität Stuttgart, D-70550 Stuttgart, Germany

4. *Adaptive linearising control of bioreactors*

E C Ferreira and S Feyo de Azevedo

Departamento 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 für Systemdynamik und Regelungstechnik, Universität 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 prove 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 of 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 arises 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 that 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 briefly 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 systèmes, CNRS, Supélec).

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 Proses, 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 Proses (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 **27th** (Friday) and **28th** (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*.