

TRIENNIAL ACTIVITY REPORT 2000 - 2002

S-L. Jämsä-Jounela M-L. Viherlaakso J. Kämpe T. Jokinen



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PREFACE



During the past twenty years the field of process control has undergone a considerable transformation. Two decades ago, the typical control-engineering graduate had a course in feedback control theory, and those interested in a career in this field secured a position in the process industries. During this period, however, the number of new control engineering positions in the process industry has declined while, at the same time, increasing emphasis has been placed on positions requiring a multidisciplinary knowledge of process engineering, automation and information technology. As a result, control theory has played a very minor role.

Due to this multidisciplinary requirement for knowledge and the latest developments in the different fields, especially in Information Technology, the need has also arisen for a change in the education and courses offered at universities. In order to fulfil the demands of industry, the students will have to be broadly educated to cope with cross-disciplinary applications and the rapidly changing technology.

The Laboratory of Process Control and Automation at the Helsinki University of Technology (HUT) provides education in process automation mainly in the fields of Chemical Technology, Forest Products Technology and Materials Science and Rock Engineering. Process automation is a special program, crossing departmental lines, that enables students in different areas such as chemical, forest product technology and material science engineering to obtain the interdisciplinary training necessary for work on process automation and its applications.

In this activity report the structure of the master's degree is presented, followed by the laboratory-industry interaction, and the new applications of teaching and education tools that the laboratory is utilizing to meet the challenges set by these new requirements. Finally, the results of the program evaluations are reported and briefly discussed. An evaluation was conducted to assure the quality of courses and outcomes of the programme in summer 2002. Web-based questionnaires were distributed to 100 M.Sc. engineers that graduated from the laboratory.

Generally the feedback from the students has been both positive and encouraging. The education of students has benefited through the involvement of industry's in the course design, thus ensuring its relevance to future careers. Employment rate was 100%. Based on these results and evaluations by the external experts Finland is experiencing a shortage of IT-skilled process engineers. Five years' experience of operating this programme has indicated that the laboratory strategy has been right selected.

Finally, I would like to thank all our co-operation partners and supporters. Special thanks are due to the industry, TEKES-Technology Agency of Finland and the Academy of Finland. The outside support has helped us to achieve these successful records in both the education and research activities.

Otaniemi 9th December, 2002

Sirkka-Liisa Jämsä-Jounela

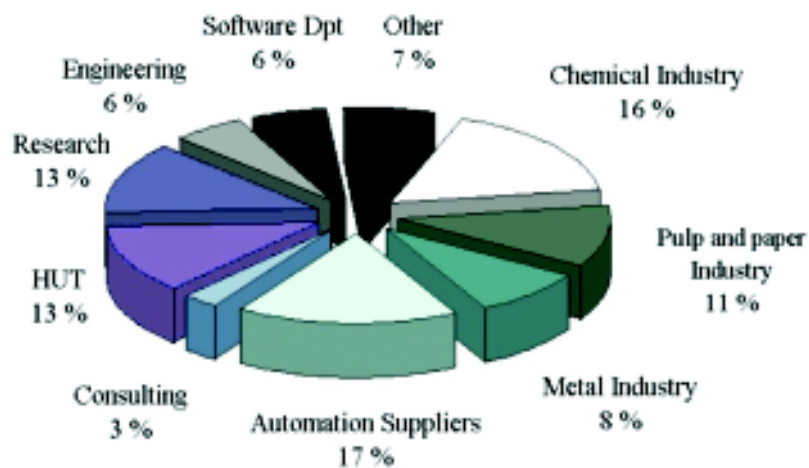
1. Introduction

Helsinki University of Technology (founded 1908) is the largest and oldest institute of engineering education in Finland. The University campus is situated about 10 km west of Helsinki in the Otaniemi area, in the township of Espoo. The number of undergraduates is about 12 000 and that of postgraduates about 2500. The basic degree offered is the master's degree in engineering or architecture (diploma engineer or architect, minimum 4.5 a). Postgraduate degrees offered are Licentiate of Technology (minimum 2,5 a) and Doctor of Technology (minimum 4 a). The University has fourteen departments. The Department of Chemical Technology comprises eight laboratories (= eight full professorships): Biochemistry and Microbiology, Bioprocess Technology, Chemical Engineering and Plant Design, Inorganic and Analytical Chemistry, Physical Chemistry and Electrochemistry, Industrial Chemistry, Polymer Technology and Process Control and Automation.

The Laboratory of Process control and Automation at the Helsinki University of Technology has been founded in 1987. The laboratory is part of the Department of Chemical Technology. The aim of the laboratory is to serve all fields of process technology -chemical, metallurgical and forest products -in terms of process automation.

The laboratory gives courses in process modelling, simulation, control, optimisation and automation as well as in production control. The undergraduate students typically have a few years background of process engineering studies, after which a one-to-two -year portion of automation studies.

This report describes briefly the staff, facilities and research activities of the laboratory of process Control and Automation during the years 2000 - 2002.



The employment of the students after graduation.

2. Personnel

2.1 Teaching staff:

Jämsä- Jounela Sirkka-Liisa	D.Sc (Tech.), Professor, Head of the Laboratory
Anna Soffia Hauksdóttir	Docent, Professor
Mikko Vermasvuori	M.Sc (Tech), Senior assistant
Timo Malmi	M.Sc (Tech), Assistant

2.2 Administrative staff

Kämpe Jerri	M.Sc (Tech), Laboratory Manager
Viherlaakso Marja-Leena	Secretary
Holmqvist Iris	Project Secretary

2.3 Research staff (1.12.2002):

Järvensivu Mika
Komulainen Tiina
Poikonen Risto
Suhonen Jori
Jokinen Tiina
Kesti Anna Riikka
Liikala Teemu
Pikkusaari-Saikkonen Jonna
Ryynänen Timo
Suontaka Ville
Vatanski Nikolai
Adhikari Yuba Raj

(2000-2002):

Bergman Samuli
Dietrich Maija
Endén Petri
Halmevaara Kalle
Harri Ilkka
Kinnunen Marjut
Kuitunen Tatu
Kämpjärvi Petteri
Laitinen Jari
Lipiäinen Jouni
Matinaho Sami
Melin Kristian
Nevalainen Susanna
Remes Antti
Tiili Otso
Timperi Juha

3. Research Activities

The main areas of research in the laboratory are process modelling and control, supervisory & artificial control systems, and fault diagnosis. The head of the research projects is Professor Sirkka-Liisa Jämsä-Jounela.

INTELLIGENT CONTROL OF THE LIME KILN PROCESS WITH RESPECT TO ENVIRONMENTAL REQUIREMENTS

Järvensivu Mika

Further reducing environmental impacts such as the reduced-sulfur emissions will be among the major challenges facing the pulp and paper industry in the near future. It will not be easy to further decrease the emissions at modern pulp mills because all the major emission sources have already been eliminated. New strategies, such as the prevention of emissions at their source, e.g. by means of improved control of the subsequent processes, will therefore undoubtedly be required in order to conform with the present and also future environmental requirements. An increase in authorities and also public attention and awareness on environmental issues together with intensifying interest in the artificial intelligence (AI) and intelligent systems were also prime motivator for this thesis work.

The primary objective of the research, which has been carried out as a co-operative effort between academic and industrial parties, has been to lower of the total reduced-sulfur (TRS) emissions from a pulp mill by means of intelligent control techniques. The research was focused on the lime reburning process, which is one of the main sources of the TRS emissions at modern pulp mills. In addition, the environmental requirements for lime kilns have become tighter and even at well-managed mills, the emissions tend periodically to exceed the limits set by the authorities. It has also been widely recognized that control of the rotary kiln used for lime calcination is, in many respects, a demanding task. So far, most of the kilns have therefore been operated without supervisory-level control system. However, there are outstanding economical and the environmental improvement potentials associated with improved control. Hence, supervisory-level control of the lime reburning

process is undoubtedly a prospective application for intelligent control techniques.

In the first phase of the research, a comprehensive study of the operation of the lime reburning process was carried out at one of the major Finnish pulp mills, with special attention paid to the factors affecting the TRS emissions. The results showed that, in addition to the considerable enhancement potential in the performance of the kiln process operation, improved kiln control is also a feasible means to reduce emissions. An overall supervisory-level control schema that takes into account both the environmental and operational requirements, was then designed on the basis of the results of the study. The supervisory-level control system, embedded with a certain degree of intelligence, was then incrementally developed and implemented at the pulp mill. The control structure combines both feedforward (FF) control models and supervisory-level feedback (FB) controllers that are based on the linguistic equation (LE) approach, strengthened with certain capabilities for adaptation and constraint handling. Advanced capabilities and highly developed functionality of the control system were achieved by combining information from different knowledge sources, and by using appropriate techniques to solve each of the recognized problems. On the other hand, the complexity of the lime reburning process was handled by implementing a modular system structure and by taking advantage of an incremental system development approach.



The results obtained during extended testing periods of the system demonstrate that the proposed control schema can be successfully realized in an industrial environment, and that it also provides quantifiable benefits in both the economical and ecological respect. The major benefit from the ecological point of the view was an almost 30 % decrease in the mean of the TRS emissions and a considerable reduction, about 90 %, in the proportion of high emissions periods. The main verified economical benefits were an increase of about 5 % in the long-term production capacity. Improvements in returned lime quality and enhancements in the energy efficiency were also obtained compared to the situation during manual operation.

USE OF HYBRID AND DYNAMIC SIMULATION MODELS THROUGH THE LIFE-CYCLE OF A PAPER MACHINE

Laukkanen Ismo

In this project a mathematical model of base paper production process was developed. The dynamics of stock and water systems of a modern paper mill was studied using a mechanistic hybrid simulation model. The combined response of the process equipment and the control system under the transient operational conditions were investigated; both major process equipment and paper mill control structures are included in the simulation model. The effects of the transient operational situations on the water usage of the paper mill were examined.

The simulator was developed during the paper mill design project. The simulator was used for the verification of process and control design, operator training and process analysis studies. All applications were performed before start-up of the plant, which was possible because mechanistic high-fidelity simulation models were used. The models were incorporated into a simulation program called APMS, which can be used to analyze the dynamics of a papermaking process.

On a basis of the research the extended life-cycle concept for using hybrid dynamic simulator through the life-cycle of paper machine was proposed. Optimally the life cycle of dynamic simulator starts at the design phase of the paper mill and follows the life cycle of the mill. The same model can be used in the following application areas: process and engineering, operator training, research and development, and paper mill.

Dynamic process simulation, based on high fidelity mechanistic models, turned out to be a powerful tool for verification of process and automation design as well as for operator training. In future, it provides a strong basis for the virtual paper mill and product development environments as well as for advanced multimedia-training systems.

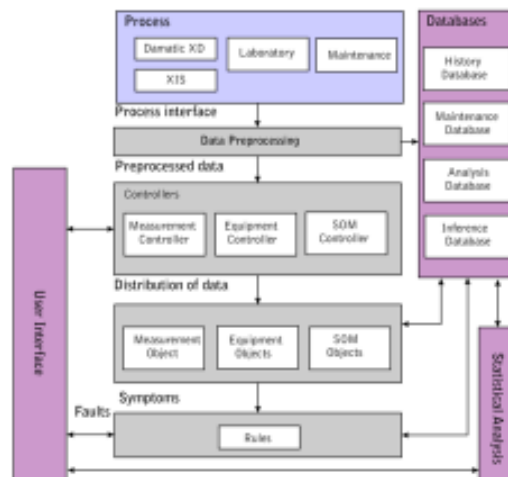
FAULT DIAGNOSIS SYSTEM FOR THE OUTOKUMPU FLASH SMELTING PROCESS

Vařavuori Eija, Salmi Tomi, Grönbärj Marko, Haavisto Sasa, Endén Petri, Vermasvuori Mikko

The aim of this project was to develop a fault diagnosis program for the Outokumpu copper flash smelting process using Kohonen Self-Organizing Maps in conjunction with heuristics rules.

The purpose of the fault diagnosis system was to detect abnormal process states and inform the plant operator accordingly. A process deviation from the normal operating range is often caused by equipment malfunctions or an incorrect control strategy. Early detection of undesirable process states enables the execution of correcting actions, thus minimising the damage caused by process malfunctions.

The implemented fault diagnosis system consists of a process interface, data preprocessing, data controllers, and symptom generation objects and rules. The inferencing results are stored in a database, which can be used to perform a statistical analysis of the faults. The structure of the system is presented in the following picture.



The monitoring and classification are performed by using Self-Organizing Maps (SOM). The SOM is a neural network algorithm which is used to form a neural network model of an unknown system based only on the data received from the system. The nature of the phenomena monitored with SOMs differ, some of them being closely linked with process control and process disturbances, while the rest monitor the states of the process. One aim was to train a SOM for the quality of the feed material, which is the most important phenomenon that affects process control in copper flash smelting process.

The overall state of the process was monitored in order to detect undesired process states because a deviation from the desired state cannot always be considered as a direct process disturbance. From an economic point-of-view, it is just as important to detect a decrease in the quality of the product as to detect an equipment failure; both lead to a reduction in productivity and profitability. The monitored process states were viscosity of the slag and the matte, temperature of the waste heat boiler, and the sooting, i.e. cleaning, of the boiler or the gooseneck.

The following actual process disturbances were searched for: flooding of the feed material, aggregation of feed material in the concentrate burner, formation of dust aggregations inside the boiler or the gooseneck, and malfunctions of the fields of the electrostatic precipitator and gas blower. The most important part of a rule-based fault diagnosis system is the rules that are applied. With well functioning rules a very effective system can be built while, on the other hand, a program cannot predict phenomena correctly if its rules are false or feeble.

In the system the rules are always connected to a specific piece of equipment, and can be formed using only those variables that are known for that equipment. This prevents the formation of illogical rules, that may be the reason why systems show unexpected behaviour. Rules that are based on equipment also make it possible to know which rules are affected if certain changes are made in the process equipment.

The fault diagnosis system has been giving promising results in both process monitoring and detection of the condition of process equipment failures.

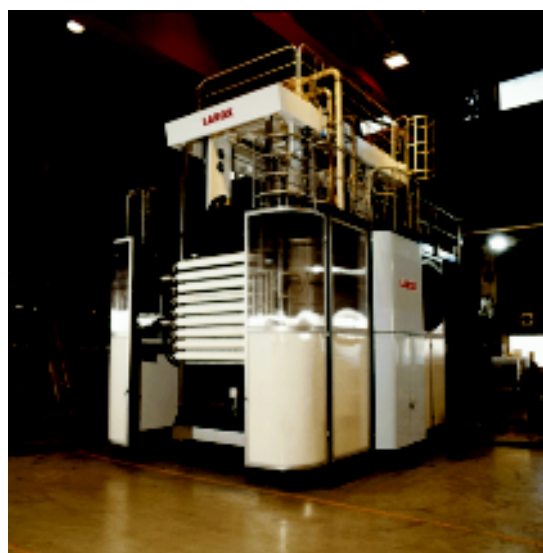
AN INTELLIGENT, INTEGRATED CONTROL SYSTEM FOR A PRESSURE FILTER

Kämpe Jerri , Vermasvuori Mikko, Rynnänen Timo, Kesti Anna

Artificial intelligence methods like expert systems and self-organizing maps have proved to be excellent tools for the control of mineral processes. This technology is currently being embedded directly into process equipment like dewatering filters. AI methods can be seen most applied in industrial applications since 1991 compared to other methods. They are used in nearly 40 % of all applications reviewed, and therefore represent the most important methods applied in the control and monitoring of MM processes.

Separation of solids from a liquid by a porous medium or screen, which retains solids while allowing the liquid to pass, is called filtration. The pressure filter can be divided into eight subsystems: slurry feeding system, water pressing system, air drying system, cake washing system, cloth washing system, hydraulic system, discharging system and control system. Since in filtration the slurry volumes are extremely large, any downtime of the process is expensive.

An intelligent control system has been developed for a pressure filter. The application has been programmed with platform independent object oriented programming language, Java.



The remote operating service system is a part of the fault diagnosis module. In addition to the implemented system the plant site needs a database server (SQL server connected to a Larox pressure filter), an IIS server, workstations, and a

local area network. At the client end there are workstations, and both ends are connected to each other via the Internet. Data are transported using a browser and HTTP as the interface. Due to security reasons, all data transmissions on the Internet between the plant and the client are encrypted with a DES algorithm, and access to the local network is permitted only through the firewalls. The encryption key is pre-shared, and encryption/decryption of the data limits the capacity to approximately 8 Mb/s. The databases include measurements and the learning part.

The aim of the learning database is to suggest possible optimal control parameters to the operator. Suggestions are based on data from previous operation cycles.

The structure of the system is modular in order to keep it easily expandable and maintainable. The overall system consists of the modeling, classification, economic, fault diagnosis, control and database modules. The modeling module contains models of the different operating stages of the filter.

The aim of the optimisation is to maximise the capacity and to decrease cycle time. Economic aspects are followed on the basis of operating costs calculated from on-line measurements. The determination of the maximum capacity is based on online classification of feed type, predicting models of filtration behaviour and a self-learning database.

The main aim of the classification module for the pressure filter control system is to train a SOM using information about different feed compositions, and to determine for each neuron the correct values of the variables used in control. Measurements for feed type classification in filtering depend on the installation and could be for example the particle size distribution and the density of the slurry.

The preliminary testing of the modelling module has been performed in the pilot plant. Testing period of the whole integrated system in the industrial scale has been started.

INTEGRATED MONITORING AND FAULT DIAGNOSIS SYSTEM FOR PROCESS EQUIPMENT AND UNIT PROCESSES

Bergman Samuli, Komulainen Tiina, Kämpjärvi Petteri, Nevalainen Susanna

The aim of this project is to develop a modular system for process monitoring and fault diagnosis. The goal is a software prototype for monitoring the process states and process equipment especially in chemical unit processes.

In the first part of the project control performance indices were developed and tested. The model predictive controller was implemented to control the quality of the product. Control performance calculations were implemented in the controller. A performance index that accounts for restrictions of controlled and manipulated variables was also developed. Indices were also developed for supervision of error signal and control moves. Using prediction error variance to evaluate control performance gave promising results. With prediction error variance, device faults were detected. The performance indices applied to control signals were able to detect aggressive control action. Indices developed for supervising process constraints were able to detect situations where the value of a controlled or manipulated variable was at its boundary.

The second part of the project consisted of a study of different fault detection and process monitoring methods applied in the chemical process industry and implementation of some applicable methods to monitor the dearomatization process. The methods were first tested with simulator data and later online with real process data from Fortum oil refinery. Artificial neural networks, fuzzy logic and statistical multivariable methods including principal component analysis and partial least squares were the selected methods to be used with a simulator.

Both self-organizing maps and projection onto latent structure models gave promising results. Principal component pre-processing clearly improved the SOMs' ability to classify the process states. The drawback of the PLS model was its inability to identify the different abnormal states. In practice, the use of SOMs for process monitoring might be easier for a process operator, since the map with coloured neurons is very visual.

The results showed that variables have a significant effect on performance of the models. Monitored process variables should be selected based on both principal component analysis and process knowledge. Constructing computational variables that describe the monitored process phenomena is of great importance. The second part of the project also included an online fault diagnosis and model updating system for ethylene plant. The aim was to detect faults in analyzers and reconstruct missing measurement values.

The project was done in collaboration with Neste Engineering and the National Technology Agency of Finland, Tekes.

INTELLIGENT PILOT FLOTATION CELL WITH FIELD DISTRIBUTED CONTROLS

Timperi Juha, Poikonen Risto, Kämpe Jerri

The aim of this project was to build a field distributed control (FDC) based automation system for a pilot flotation tank in laboratory of process control in HUT and to research the possibilities in utilizing digital fieldbus technology in device diagnostics. The goal was to build an automation system similar to commercial Procon system. The main difference to Procon system was utilization of digital fieldbus instead of analog 4-20 mA signaling. Fieldbus technology was chosen to be Foundation Fieldbus because it fits well to be used in device diagnostics.

The flotation cell process in our laboratory is a slightly modified version of the Outokumpu TC-3 TankCell. An additional 3.5 m³ tank is used to provide circulation.

The process is equipped with state of the art Foundation Fieldbus instruments. Three digital Neles Automation valve positioners are used to control the cell output valves and air supply valve.

Level, flow and pressure measurements are implemented using Smar, Rosemount and Miltronics technology. An Ilmeco flotation air blower and feed circulation pump are controlled by Vacon frequency converters. The fieldbus universal bridge (DFI302) that acts as a link between foundation and ethernet network was also from Smar.

Foundation Fieldbus offers a possibility to use field-distributed control. This means that all the calculation and control actions are made by field devices, not by PLC. This enables a "Plug'n Play" type installation via a standard Ethernet cable into a Outokumpu PROCON 2100NT Process



Management Station without any wiring to the PLC. When system was implemented, an architecture that would be scaleable and modular as possible was aimed. Therefore use of proprietary interfaces was not appropriate. De facto interfaces standards like OPC and ODBC was used in system integration. System was configured using Syscon 302 from Smar and the user interface software that was used to control the process was GE Fanuc's Cimplicity. Both of these softwares works via OPC server.

WIRELESS AUTOMATION IN PROCESS INDUSTRIES

Suhonen Jori

The aim of this project was to find out the current status and future trends of wireless automation especially in process industries. The project was carried out in co-operation with Nokia.

The project concentrated on the three main parts. In the first part several case studies from the industry were studied and especially the suitability of these technologies for process automation purposes was of great interest. The technologies included all the relevant network technologies, connection protocols as well as application development technologies used nowadays and in the near future. The case studies

included many interesting and innovative applications using wireless automation technologies ranging from simple small-scale systems to entire communication systems of a factory. The most interesting ones were wireless user interface based on a WLAN technology and a sensor ball application where a sensor-ball goes along with the process liquid collecting data from the process on the way.

In the second part a comprehensive questionnaire study was carried out. Altogether 220 professionals of the automation industry answered the questionnaire. The questions covered wireless automation from several aspects and the results from the questionnaire study told us how the respondents saw the current status and future trends of wireless automation. We can conclude that the respondents strongly believe that in the future wireless technologies will be used more and more extensively for process automation purposes. In particular, the use of wireless automation in process monitoring and process control applications seems to be increasing rapidly.

In the last part a wireless test environment was built in the Laboratory of Process Control and Automation using Bluetooth and commercial GSM-network. The aim of the environment was to simulate a communications structure of a tank far away from the backbone system. Bluetooth was used for short-range communications between meters and an SMS gateway. SMS was then again used for long-range communications between the gateway and the backbone system.



Experiences gained from the test environment were encouraging. First of all the system seemed to work very well for the job and secondly the system was relatively easy to implement and to configure. The only small problem with the system was the use of SMS, which cannot be used in real-time meter reading applications. Using e.g. GPRS instead would solve this problem. In the future the environment will be used for educational and scientific purposes.

SOFTWARE FOR THE LEVEL CONTROLLER TUNING OF FLOTATION CELLS IN SERIES

Dietrich Maija, Halmevaara Kalle, Tiili Otso

The main goal of this project was to develop tuning software for level control of slurry in different Outokumpu flotation cells. Mathematical models were constructed for the first flotation cell, intervening cells and the last cell in the series.

A number of models were developed: The properties of an ideal tank were assumed and classical PI controllers tested, physical properties of the cell (shape) were included, the feedforward control strategy was implemented, dynamics of the Larox pinch valves and Outokumpu Dart-valves were included in the models and the valves were resized, viscosity effect on valve sizing was considered

Mathematical models for the double cells were constructed in a similar manner. The principle differences compared with the mathematic models of single cells in series are that, in a double cell, both pulp levels are controlled by manipulating a control valve in the second cell outflow.

The simulation of the configurations of three and six TC-50 cells in series resulted in parameters for the PI controllers. All the disturbances introduced into the system could be compensated using both valve sizes.

Different valve sizes and different cell types had an effect on the proportional gain of the PI control: the proportional gains were larger when using valves sized according to the ISA standard than oversized valves. Similarly, the proportional gains were larger in the case of ideal tanks than with cells. Higher proportional gains reduce the settling time of the system in PI control. The Opening speeds (from 0% - 100 %) of the valves have been estimated to be 30 seconds regardless of the valve size, i.e. the bigger the valve, the shorter the rise time.

The influence of valve sizing and additional feed forward control were also studied in a pilot plant. The test configuration consisted of a flotation cell, pulp circulation cell, pulp pump, air feed device and two different control valves. The inflow was measured with magnetic flow meter and the pulp level with a float. The tests were performed with flotation cell with similar geometries (as described above). The results achieved were analogous to those obtained in the simulations. The control performance was

noticeably improved by adding the feed forward control. It was also found that an adaptive feed forward control gain could result in even greater improvements in control performance.

The geometry of the cell had the greatest effect on the performance of the level control. A difference in performance was clearly evident when the same configurations with ideal cells and with different geometry cells were compared. In every case the results were clearly better.

Feed forward control implemented with PI control improved the compensation of the disturbances in every case. An adaptive feed forward control gain could result in even bigger improvements in control performance. In future the research extends to determine the effects of recycling flows on the control strategy.

LEVEL CONTROL STRATEGIES FOR FLOTATION CELLS

Kämpjärvi Petteri

Flotation is a difficult process to run efficiently. One way to make flotation performance better is to improve cell level control. However, controlling pulp levels in flotation cells is a complex control task because of strong interactions between the levels in the flotation cells. Therefore advanced controllers are needed to give good level control. This research dealt with a model of six flotation cells in series. Simulations were performed to compare different control strategies. Four control strategies were considered: one SISO controller and three different MIMO controllers. It was shown that level control performances of the MIMO controllers are significantly better than that of the classical SISO controller.

The difference between different MIMO systems were somewhat smaller. All the controllers performed robustly to disturbances in pulp feed and to set point changes. The decoupling controller had the best IAE and IDE indices. However, the decoupling controller is sensitive to model uncertainties. This also means that process changes can strongly degrade the control performance.

DESIGN AND IMPLEMENTATION OF A CONTROL PERFORMANCE MONITORING SOFTWARE

Poikonen Risto, Georgiev Zdravko, Zuehlke Ursula

The number of control loops used in industry is growing continuously and there are problems in keeping them well tuned. In order to ensure highest product quality it is essential to maintain the control systems in an adequate manner. An improved control performance has a considerable effect on variations in end product quality, and thus on the productivity of the plant. Additional benefits are low consumption of raw materials and energy, as well as a longer life span of the instruments.

During the last decades considerable effort has been placed on developing suitable indices for evaluating control performance. The evaluation methods can be divided into two categories: stochastic and deterministic methods. The most widely studied stochastic indices are those based on using of MVC (minimum variance controller) calculation as a benchmark. Deterministic indicators are more informative in the case of a sudden load disturbance or a set point change. Various dimensionless indices for setpoint changes have been proposed in the literature. Different kinds of indices were tested using a flotation cell process model that was programmed in Matlab Simulink toolbox. Indices that functioned well in the simulations, and which were applicable to on-line monitoring, were chosen for further development.

The indices were implemented using the GE Fanuc CIMPLICITY HMI Plant Edition and its script language. Cimplicity is a user interface program for process control, and is widely used in flotation processes. Outokumpu pilot Tankcell and the above-mentioned programs were to test the indices in practice. The cell instruments were connected to the Foundation Fieldbus and controlled by Smar DFI 302. The controller unit was connected via Ethernet to the OPC (OLE (Object Linking and Embedding) for process Control) server, and Cimplicity used the OPC port to control the flotation cell.

Simulations and tests performed with the pilot flotation cell proved that the indices provided the necessary information about the control performance. This monitoring tool could be used in plants to monitor the key controllers for improving process control and product quality. More attention will be paid to the economical effects in the future research.

INTELLIGENT MODELLING AND SIMULATION APPROACHES TO HYDROMETALLURGICAL PROCESSES

Cziprian Zoltan, Grau Rodrigo, Kojo Tero

The use of computer simulation is now a basic tool for process design and optimization as evidenced by its increasing use of practicing engineers through commercially available simulator software products. Engineers, in charge of designing equipment for the hydrometallurgical plants have to be able to select the most suitable equipment for each application and to predict the performances under different process conditions. In order to allow the process engineers to concentrate on their task, the simulation software has to offer a user-friendly interface combined with quick and accurate calculations.

A new simulator is under development, which offers a fully graphical user-interface, open database connectivity and application oriented unit model library. The purpose of the developed software is to integrate the already existent calculation algorithms, database files and process unit models into a completely new user-friendly and open-architecture system. The above mentioned knowledge exists in universities and companies under different representation forms. In the field of hydrometallurgy the simulation facilities offered by the available commercial software products are very limited and the unit models usually are fixed. Our aim is to implement specific unit models and to adapt them to the research and/or industrial application in study. At this stage the focus is on the hydrometallurgical process, however in future the research might concentrate on other process units depending on the industrial demand.

The most important feature of this software is to gather all the following proprieties:

- graphical user interface
- specific unit models for hydrometallurgical applications
- chemical database with open connectivity
- dynamic simulation
- steady-state material and energy balance calculations
- model development possibilities

MODEL-BASED CONTROL OF COPPER SOLVENT EXTRACTION - ELECTROWINNING

Ville Suontaka

During the last two decades copper leaching, solvent extraction and electrowinning (LX/SX/EW) process has become an important process option for producing copper from a low-grade oxidized ore. LX/SX/EW-copper production has grown very fast during the last decade and further growth can be expected. At the moment there is about 50 plants in the world producing copper with LX/SX/EW-process. In year 2001 world LX/SX/EW-copper production was about 2.8 million tons of which about a half was produced in Chile.



The process is relatively young and intrinsically quite stable and therefore previously development has mainly focused on the process equipment. This has led to a low level of automation compared to other mineral processing operations. Usually only a low-level regulatory control, where controller set points are set manually, is implemented. Improvements in plant automation would make it possible to keep process parameters near their optimal values which would increase amount of copper produced, reduce amount of chemicals and energy used and improve copper quality. These improvements would lead to remarkable economical benefits.

The aim of this project is to study possibilities to use model-based control in copper LX/SX/EW-process and to find out the possibilities to improve process performance and economics with such control strategy.

First current status of modeling, simulation and control of the LX/SX/EW-process was studied. It was found out that research on advanced control of the process has not been published widely.

Next a process monitoring application for copper SX/EW-process is developed. The application is based on steady-state mass balances of the process. Flow measurements and on-line analyzer assays are used to calculate amount of copper transferred in different stages of the process. These values are compared to the calculated theoretical values. The application assists process operators in process control and functions as a basis for control application to be developed in the future.

The project is done in a co-operation between Outokumpu Technology Oyj.

KNOWPAP - MULTIMEDIA LEARNING ENVIRONMENT FOR PAPER TECHNOLOGY AND PAPERMILL AUTOMATION

Mäenpää Tom

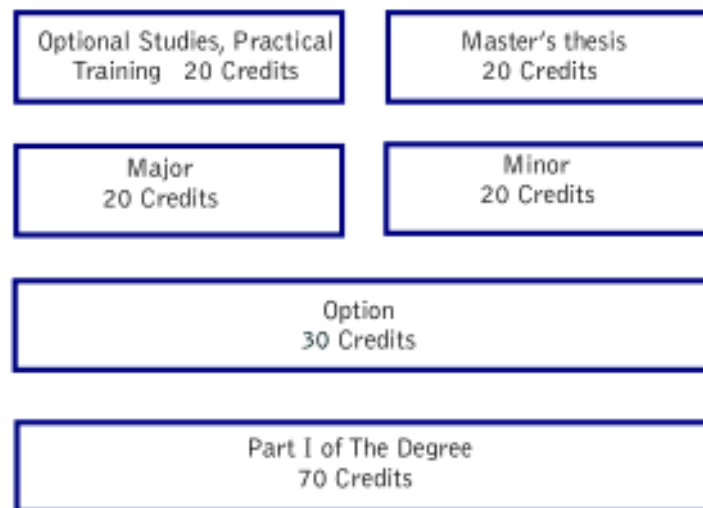
KnowPap is a new generation learning environment covering paper technology, process control, paper mill automation and maintenance. It consists of multimedia training material and simulation models that are accessed by a standard web browser. KnowPap is used for self-studying and as supplementary material for training within paper manufacturing companies, suppliers and consulting companies, universities and other educational institutes.

The development of KnowPap was started in 1997. The Project was managed by VTT Automation and the system was completed in the beginning of 2001. KnowPap was then already in use in the participating companies, Helsinki University of Technology, Technical Research Centre of Finland (VTT) and in more than 20 other educational institutes.



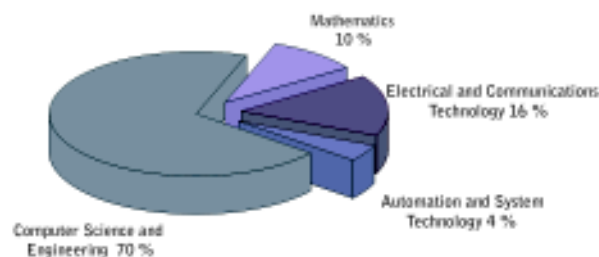
4. Structure of the Master's degree

The extent of master's degree in technology is 180 credits. The degree consists of two parts and its nominal duration has been confirmed as 5 years. Part I of the degree consists of approximately 70 credits and includes mathematical and scientific subjects, such as mathematics, physics, information science and general studies as well as foreign languages. In part II of the degree the student chooses process automation as his/her major and minor which can be chosen outside the degree programme or even from another university of technology. Part II of the degree in process automation also contains studies in computer science and related topics. The topic of the M.Sc. thesis is chosen to fit within the major subject.



Major students of process control are able to include several courses in computer science and engineering in both major and option studies. Students can choose courses from Computer and Information science, Information Processing Science, Software Technique, Telecommunications Software and Applications, Interactive Digital Media, Contents Production and Usability Research.

The questionnaire study from graduated students indicated that a good knowledge in computer science has been an important competence for our students working in the Finnish process industry.



Optional studies by different fields

5. Teaching activities

5.1 Undergraduate studies

Kem-90.131 Optimisation (2 cr)

Lecturer: M.Sc.(Tech.) Tatu Kuitunen
Contents: Applications of optimisation methods in process industry. Laboratory exercises with the MATLAB optimisation toolbox.
Literature: T.F. Edgar and D.M. Himmelblau, Optimisation of Chemical Processes, McGraw-Hill 1988. Course Notes.

Kem-90.139 Process Industry Measurements (2 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela
Contents: Process Industry Measurements. Guest speakers from the industry.
Literature: O.Aumala, Teollisuusprosessien mittaukset, Pressus Oy, Tampere, 1996 Course Notes
Knowpap – Multimedia learning environment for paper technology and paper mill automation.

Kem-90.147 Basic Course in Process Automation (2 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela,
M.Sc.(Tech) Mika Järvensivu
Contents: Automation in process industry. Instrumentation and special measurements at the plant. Dynamic modelling and simulation of the processes. Feedback control. PID- controller and its tuning. Structure of the automation system. Design and planning of the automation project. Course is a composed of series of lectures given by experts in process automation.
Literature: Course Notes.

Kem-90.148 Process Modelling and Simulation I; basic course (2 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela
Contents: Physico-chemical modelling and simulation of the unit operations in process industry. Laboratory exercises with the SIMULINK and MATLAB toolboxes.
Literature: W.L Luyben, Process Modelling, Simulation and Control for Chemical Engineers, McGraw-Hill, 1990.
Course Notes.

Kem-90.149 Process Modelling and Simulation II (2 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela
Contents: Practical experiment design. Modelling of discrete systems. Identification methods. Laboratory exercises with SIMULINK and MATLAB system identification toolbox.
Literature: W.J. Diamond, Practical Experiment Design for Engineers and Scientist, Van Nostrand Reinhold, 1981.
R.Isermann, Identifikation Dynamischer Systeme, Band I-II, Springer-Verlag, 1988. Course Notes

Kem-90.156 Process Automation Project Work (3 cr)

Lecturer: Lab. Manager Jerri Kämpe
Contents: Configuration and Implementation of process automation system. Laboratory with Wonderware FactorySuite 2000 and Proscon 2100 automation system. Guest Speakers from the industry.

Kem-90.160 Information Technology In Process Control (3 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela
Contents: Planning methods, tools and interfaces supporting application software of process automation. A small scale implementations of process automation. The objective is to learn through practice. The content of the course varies every year. The course is designed for the students who major in process control.
Examination: assignments, final exam

Kem-90.161 Process Control Structures and Applications (4 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela
Contents: Review of the classic and modern control and theory. Process control of basic functions: level, pressure, volume flow and mass flow, energy, and concentration. Process control of common unit processes and plantwide control systems. Laboratory exercises with MATLAB model predictive control and control system toolboxes and SIMULINK.
Literature: Course Notes

Kem-90.162 Intelligent Process Control Methods (3 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela
Contents: The aim of the course is to provide an overall understanding of the application of artificial intelligence (AI) in process control. The course will give an insight how AI techniques can be used to improve control systems. Special emphasis will be put on intelligent control-expert control, fuzzy control and the use of neural networks for control. The course will combine conceptual
Examination: Formal lectures, session notes, assignments, final exam.
Literature: C-T. Lin and C.S. George Lee, Neural Fuzzy systems, Prentice Hall, 1996.
Course Notes.

Kem-90.163 Production Planning and Control in Process Industry (3 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela
Contents: Operations Planning and Control: Forecasting for Operations, Inventory Planning and Control, Operations, Scheduling and Statistical Quality Control Methods. LINEAR PROGRAMMING: Simplex Method; MATHEMATICAL PROGRAMMING: Network analysis, Dynamic Programming, Integer Programming, Nonlinear Programming; PROBABILISTIC MODELS: Queuing Theory, Inventory Theory, Forecasting. Laboratory exercises with Arena.
Literature: F.S. Hillier and G.J. Lieberman, Introduction to Operations Research 5. Ed. McGraw-Hill, 1990
W.D. Kelton, R.P. Sadowski and D.A. Sadowski, Simulation with ARENA, McGraw-Hill, 1998, 547 p.
Course Notes

Kem-90.173 Control and Information Systems in Pulp and Paper Industry A (3 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela

Contents: The course gives an overview of the control and information applications in the pulp and paper industry at processes, department, mill and corporate levels. The basic hardware solutions, models, functions and results achieved will be discussed. Further needs and trends in automation and information technology will also be presented. This course is mainly for linkage program students and for those students that have selected process as their minor subject.

Kem-90.174 Control and Information Systems in Pulp and Paper Industry B (3 cr)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela

Contents: The course gives a detailed knowledge of existing control and information system applications in the pulp and paper industry at processes, department, mill and corporate levels. It provides an overview of classical control and basics in digital control methods. Also modern control strategies such as multivariable control and predictive control will be discussed. This course is for major students of process automation and partly organized together with the courses Kem-90.152 and Kem-90.173.

Kem-90.V Instrumentation and Control (1,5 cr)

European Mineral Engineering Course (EMEC) (2,5cr) (12.3.2001- 16.3.2001)

Lecturer: Prof. Sirkka-Liisa Jämsä-Jounela

Contents: The aim of the course is to give an overall understanding of process automation: the basic hardware solutions and functions, instrumentation and special instruments, dynamic modeling and simulation of chemical processes, feedback control, PID-controller and its tuning, feedforward control, ratio and cascade control, control applications in mineral processing industry

Literature: Course notes



5.2 Post-graduate courses

The laboratory is involved in two graduate schools: Graduate school in Chemical Engineering (GSCE) and international Ph.D Programme in Pulp and Paper Science and Technology (PAPSAT). The course catalogues are available in <http://www.abo.fi/gsce> and <http://www.hut.fi/Units/Faculties/P/Papsat/>. The following courses organised by the Laboratory of Process Control and Automation were included in the course catalogs of these graduate schools.

Kem-90.V Linear Control Systems (5 cr) (28.8.2000 - 8.9.2000)

Lecturer: Prof. Anna Soffía Hauksdóttir, University of Iceland, Iceland
Prof. Tom McAvoy, University of Maryland, USA

Contents: Solution of the state equations, The matrix exponent, Modal decomposition, Observability and controllability, Similarity transformations from a general form over to a special form, Kalman's decomposition, Dual systems, output, Definitions of special forms and their properties, transfer function coefficients, Pole placement and design of observers, Similarity transformations to observer and the controller forms, Ackermann's formula, A combined observer/controller - the separation principle, Observer/controller in transfer function form, reduced order observers, Optimization, Optimization of zeroes, A linear system of equations of the form $Ax = y$, Multivariable systems, minimum forms, zeros, Control of multivariable systems, decoupling controllers, Balanced realization and model

Literature: W.L. Brogan: Modern Control Theory, Prentice Hall, 1991, 736p
K. Furuta, A.Sano, D.Atherton: State Variable Methods in Automatic Control, Wiley 1988, 220p
T. Kailath: Linear Systems, Prentice Hall, 1980
Arnar Gestsson: Multivariable Systems Synthesis - Decoupling Controller for a Ferrosilicum Furnace. M.S. -theseis, Faculty of Engineering, 1994
F. Zhou, J.Doyce, K. Glover: Robust and Optimal Control, Prentice Hall, 1995, 596p



Professor Anna Soffía Hauksdóttir and her students

Kem-90.V Advanced Topics in Model-Based Process Control (3 cr)

Lecturer: Prof. Frank III Doyle, Department of Chemical Engineering, University of Delaware, USA

Contents

- A. Single Loop Internal Model Control (IMC) Design**
Structural analysis, PID tuning using IMC
Extensions: Unstable systems, RHP zeros, Constraints, Time Delays
- B. Model Predictive Control Motivation**
Components, Vendors, Models for MPC, Process Identification, Unconstrained MPC, Properties, Constrained MPC, Nonsquare systems, State estimation, Nonlinear MPC
- C. Grade Transition Control**
General problem, Cost functions
Control strategies: Nonlinear direct synthesis, Gain scheduling, Nonlinear MPC
Application examples: Paper machine, Pulp digester, Polymer reactor
- D. Process Identification**
Model structures: IR, SPR, State-space, ARMAX (BJ, OE, BJ, ARX, etc.)
Identification methods: Prediction error methods, Correlation methods, Subspace ID, Recursive methods
Practical issues: Input sequence design, Structure selection, Validation
- E. Run to Run Control**
Introduction, overview, review of adaptive control
Iterative learning control for batch-to-batch
Optimization framework for run-to-run control
Advanced issues -incorporation with MPC

Literature:

- Ogunnaike & Ray - Process Dynamics, Modeling and Control (Oxford)
- Morari & Zafirov - Robust Process Control (Prentice)
- Ljung - System Identification : Theory for the users (Prentice)
 - Topic B: Ogunnaike & Ray - Chapter 27
 - Topic C: Journal Articles
 - Topic D: Ogunnaike & Ray - Chapter 13 (also Ljung)
 - Topic E: Journal Articles



Professor Frank III Doyle with his students in Suomenlinna

6. Hardware and software facilities

6.1 Laboratory Equipment

- fully instrumented and automated heat exchanger system consisting of four pilot heat exchangers
- fully instrumented and automated mixing tank process.
- fully instrumented and automated flotation cell process, with Foundation Fieldbus

6.2 Automation Systems

Outokumpu TankCell Automation system

- SMAR DFI302 Foundation Fieldbus system
- SMAR System 302 configuration Software
- Bluegiga wireless process automation system
- SAMR OPC-server
- Cimplicity Control Software (HMI)
- MS SQL 7.0 database

Automation system is connected to the Outokumpu tankcell research&teaching process.



Outokumpu Procon 2100 NT automation system

- GE Fanuc 90-70 Programmable Logic Controller
 - SMAR PCI302 Foundation Fieldbus system
 - Cimplicity Control Software
- Automation system is connected to the mixing tank teaching process.

Wireless Automation

A wireless test environment using Bluetooth and SMS technologies has been built in order to simulate the communication structure of a flotation cell located far away from the backbone system.



PC-based automation system

- Opto 22 remote I/O unit, with Ethernet connection
 - Wonderware FactorySuite 2000 software
- This automation system is connected to the teaching process containing 4 different heat transfer units.

6.3 Computers and related hardware

Desktop computers

Processor Model		Amount
Intel Pentium IV	2 400 MHz	4
Intel Pentium IV	2 000 MHz	2
Intel Pentium IV	1 500 MHz	2
Intel Pentium III	1 000 MHz	3
Intel Pentium III	800 MHz	2
Intel Pentium III	750 MHz	2
Intel Pentium III	700 MHz	1
Intel Pentium III	650 MHz	2
Intel Pentium III	600 MHz	1
Intel Pentium III	550 MHz	1
Intel Pentium III	500 MHz	1
Intel Pentium II	450 MHz	1
Intel Pentium II	400 MHz	2

Laptop computers

Processor Model		Amount
Intel Pentium	2 000 MHz	1
Intel Pentium	1 133 MHz	1
Intel Pentium	700 MHz	2
Intel Pentium	MMX 233 MHz	1
Intel Pentium	133 MHz	1

Primary Network Server Computer

- Intel Pentium III Dual 1 133 Mhz
- 512 MB RAM
- 2 * 18 GB and 2 * 36 GB SCSI hard disks using RAID 1
- Windows 2000 Server Operating system

Secondary Network Server Computer

- Intel Pentium II Dual 350 Mhz
- 512 MB RAM
- 4 GB and 2 * 36 GB SCSI hard disks
- Windows 2000 Server Operating system

Network SQL- and Www-Server Computer

- Intel Pentium III Dual 933 MHz
- 512 MB RAM
- 2 * 18 GB and 2* 36 GB SCSI hard disks using RAID 1
- Windows 2000 Server Operating system
- Microsoft SQL Server 7.0
- Microsoft Internet Information Server 5

Protected Network Server Computer

- Intel Pentium 133 MHz
- 128 MB RAM
- 2 GB and 9 GB SCSI hard disks
- Windows NT Server 4.0 Operating system

Printers

- HP Laserjet 4100DTN (1200 dpi)
- HP Laserjet 4050N (1200 dpi)
- HP Laserjet 4000N (1200 dpi) (2 printers)
- HP Color Laserjet 4500N (600 dpi)

Firewall

- Cisco PIX-506 VPN

UPS

- APCC Smart-UPS 3000VA
- APCC Smart-UPS 1400VA (2 systems)
- APCC UPS 600VA

Bluetooth

- Bluegiga Starter Kit
- Bluegiga WRAP 1260 Microserver

GSM Terminals

- Nokia 30 GSM Connectivity Terminal (2 Terminals)

Scanners

- HP ScanJet 6200c
- HP Scanjet 4c

Data projector

- Infocus LP 350
- Infocus LitePro 720

Copy Fax machine

- HP Laserjet 3330

Digital video camera

- Sony Mini DV DCR-PC10E PAL

Digital camera

- Canon Digital Ixus 300

Camera

- Olympus m-zoom wide 80

6.4 Software

Control Engineering Software

- 20 licenses of Wonderware Factory Suite 2000 (containing Intouch, Industrial SQL Server etc.)
- Matlab 6.1/Simulink www-server

Classroom licenses of:

- Wonderware Factorysuite 2000
- Rockwell Software Arena 5.0

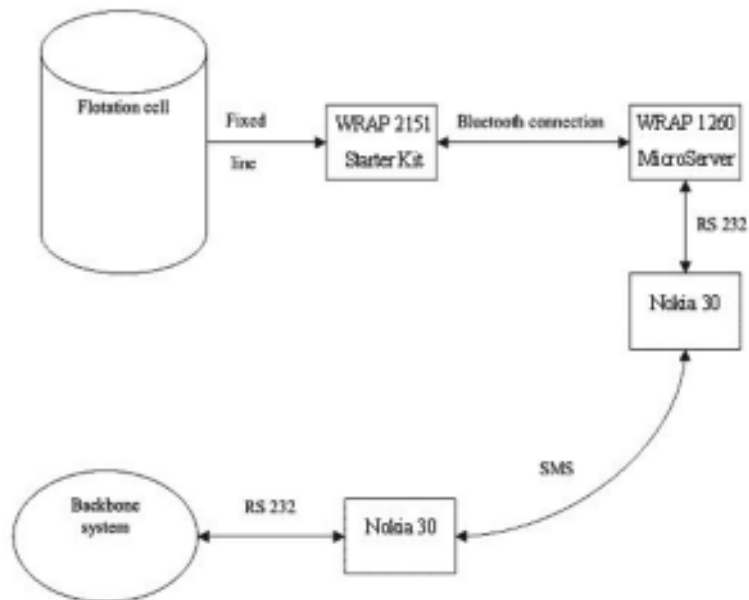
Classroom licenses are installed in the computer class room of the department of chemical engineering.

Office automation software

- Microsoft Office 2000
- Adobe PhotoShop 5.5 and 4.0
- Adobe Premiere 5.0
- Adobe Acrobat Writer 5.0
- Corel Draw 10
- Microsoft Project 98
- Microsoft Publisher 98
- Omnipage Limited Edition
- StatSoft Statistica
- Seagate Crystal Reports Developer Edition

Software and Internet development tools

- Borland JBuilder Professional
- Microsoft Visual Studio Professional Edition 97
- Microsoft Visual Studio 6.0 Enterprise
- Microsoft Visual C++ 5.0
- Microsoft Visual Basic 5.0
- Microsoft FrontPage 2000
- CompanyM Multimaker



The communication architecture of the wireless test environment

7. Thesis

Thesis for the Degree of Licentiate In Technology

Laukkanen, Ismo	Studies in using hybrid dynamic simulation through the life-cycle on of paper mill
Cziprián, Zoltan	Simulation software development for material balance calculations in reacting systems.

Thesis for the Master of Science In Technology

Chemistry:

Bergman, Samuli	Monitoring of a Dearomatization Process TMP refiner
Forsell, Marko	Instrumentation audit of sugar manufacturing process and Technical Solutions on Data Security
Georgiev, Zdravko	Control loops performance monitoring and process assessment
Grönbärj, Marko	Inference Methods in Industrial Fault Diagnostic
Kämpjärvi, Petteri	Diagnosis of process data and update of an on-line model
Laiho, Emmi	Training Material About Turbocompressors and Their Control Methods
Mustonen, Valtteri	Control Strategies of the Continuous Pressurised Three Phase Separating Tank
Muurinen, Matti	Simulation study on the control of the bed and furnace of a fluidised bed boiler
Nevalainen, Susanna	Control performance indexes in petrochemical plants
Peltoniemi, Jyrki	OPC data transfer in large-scale dynamic process simulation
Suhonen, Jori	Wireless Automation in Process Industries

Pulp and Paper:

Dietrich, Maija	Real-time economic model of paper machine operations
Hafrén, Lena	Measuring the rheological properties of surface sizes
Hevonoja, Tommi	Development and Start-up of Ultrafiltration Process Control System in a Publishing Paper Mill
Malmi, Timo	Uniformity of Quality at Metsä-Botnia Ab's Kaskinen Plant
Matinaho, Sami	Development of BCTMP mill simulation model and modelling of TMP refiner
Näränen, Janne	Simulating and Analysing the Effects of Refiner Segments on TMP-Process Using a Theoretical Model
Petäjä, Janne	Applying Remote Diagnostics in Service Business
Rönkkö, Kati	Optimising Wet End Chemistry in Wallpaper Base Machine
Ylä-Jarkko, Olli	Modelling the Technical Age of a Pulp Mill

Mining, mineral and metallurgy:

Enden, Petri	On-line testing of a process monitoring system and analysis of results
Grau, Rodrigo	Mass Balance Algorithms for Reacting Systems and Strategies for Computer Simulation
Haavisto, Sasa Lipiäinen, Jouni	Rule based fault diagnosis system for industrial processes Remote Support System for Pressure Filter - Data Acquisition and Technical Solutions on Data Security
Remes, Antti	Effects of the XRF analyzer accuracy and sampling frequency on the control performance of flotation
Sihvo, Olli Tiili, Otso	The Intelligent Field Devices - a Part of Asset Management Development and Implementation of Control Strategy for Pulp Levels in a Series of Flotation Cells
Timperi, Juha	Utilization of Fieldbus Technology in Control and Information System of a Process Device
Vermasvuori, Mikko	On-line Monitoring of Process Disturbances for the Outokumpu Copper Smelting Process

Thesis for the Master of Science in Progress

Hankimäki, Janne Komulainen, Tiina	Dynamic Simulation of Paper Machine, (VTT Automation) On-line monitoring and fault diagnosis for the dearomatization process, (Fortum Oyj, HUT)
Koskelainen, Jussi Liimatainen, Tommi	TBA Glass model of an on-line multimit calender (Metso Paper Oyj)
Nevalainen, Seppo	Dynamic Modeling and Simulation of Alumina Calcination Process, (Lurgi Metallurgie GmbH, Frankfurt)
Poikonen, Risto	The Design and Implementation of a Control Performance Monitoring Program, (Outokumpu Oyj, Tekes, HUT)
Rinta-Kokko, Pekka	Predicting of Mechanical Pulp Production, Broke Use and Electricity Costs in a Paper Mill, (KCL Science and Consulting)
Seppälä, Hannu	Numerical Simulation For Evaluating the Usability of Secondary Treated Effluent at Process Water at Mechanical Pulp Mill, (KCL)
Suomalainen, Suvi	Improving the Software Engineering Process of the Safety Related System, (Mipro Oy)
Suontaka, Ville	Model-based control of copper solvent extraction-electrowinning, (Outokumpu Oyj, HUT)
Wikström, Tua	Advanced Retention Control in Newspaper Machine, (UPM-Kymmene Oyj, Metso Oyj)

7.1 Thesis abstract for the Licentiate In Technology

Studies in Using Hybrid Dynamic Simulation Trough the Life-cycle of Paper Mill

Laukkanen, Ismo

This study focuses on the applications of hybrid dynamic simulation in the paper industry. The principles of modelling the paper machine process are introduced. A dynamic, hybrid simulator consists of continuous, discrete time, discrete event and static models which are used to model a thermohydraulic network and paper machine submodels. The simulator developed in this study was incorporated in a program called APMS, which was used as a modelling environment in this study.

A mathematical simulation model of the paper machine process was developed during the paper machine design project. The goal of modelling was to analyse the process dynamics of the new paper machine, including new process and control design concepts. There were no industrial scale experiences on the controllability of similar processes available. The combined response of the process equipment and the control system under transient operation conditions was investigated; both major process equipment and paper mill control structures were included in the simulator. Both normal and transient operation of the process were verified. As a result, the faulty operation of two control circuits was identified. Redesign and fine-tuning could be carried out before the initial start-up. It was estimated that 0.5 - 1 day troubleshooting time was saved.

The first application for the simulator was operator training, including training in normal, grade change, web break and process disturbance situations. A real process control system (Valmet Damatic XD) was used to operate the training simulator. As a result of simulator training, the start-up of the machine was very easy and the operators responsible for running the machine learnt how to operate the new process. The training turned out to be too difficult for some operators. On the basis of these results, a web-based multimedia learning environment called KnowPap was developed. The usability of

KnowPap, both in classroom training and for individual study, was investigated. It turned to be out a very good training tool for initial and intermediate training, while the full scope simulator is a good tool for advanced operator training.

The simulator was next used in process analysis studies. A problem, which has been reported in many paper mills, concerning consistency fluctuations of save-all filtrates was studied. The reason, a rapid change in the blend chest level was identified, using the simulator. The change causes disturbances in the sweetener stock composition and in the save-all filter operation. The short and long term effects of the change are observed as fluctuating filtrate consistencies and fluctuations in paper quality properties, respectively.

Based on these results, we propose that by the optimally use of hybrid models, the life cycle of the simulator follows the life cycle of the paper machine. The hybrid simulator is multifunctional, fulfilling the requirements of process and control engineering, operator training, research and process analysis applications. As a result, the quality of the design, training and process operation can be improved. All applications can be performed before the start-up of the machine, which is possible because mechanistic high-fidelity hybrid models are used. This is a very important characteristic, which makes its industrial use both practically and economically feasible. The extended life-cycle concept was tested on the industrial scale case study.

Dynamic process simulation, based on hybrid models, turned out to be a powerful tool for verification of design, for operator training and process analysis. In future, it will provide a strong basis for the virtual paper machine and paper product development environments as well as for advanced multimedia-training systems.

Simulation software development for material balance calculations in reacting systems.

Cziprián, Zoltán

The aim of this work was to develop a simulation software tool that can be used as a framework for specific process simulations. The developed simulator offers a framework for other research projects, and it is not intended to be a sophisticated chemical simulator. In this way, various chemical, mineral and metallurgical process simulation-related research projects carried out at the Helsinki University of Technology could share and extend the source code of the same framework.

The general structure of chemical process simulators is reviewed in the beginning of the literature part. The basic material and energy balance calculation theory is then presented. The two main flowsheet solving methods, namely the sequential-modular and equation-oriented strategies are compared. The sequential-modular strategy is presented in more detail because it has been used in the simulator implementation. Solution algorithms for steady state material balance calculations are presented in more detail, with special emphasis on reacting systems.

The design and implementation of the simulation software are presented in the experimental part. The software architecture and main parts of the graphical user interface are presented in detail. The structure and implementation of the chemical database are also briefly presented. The implemented dynamic and steady state flowsheet solver routines are discussed.

All the basic unit models described in the material balance section of the literature part are implemented in the simulator. As implementation of the unit models and flowsheet solvers is based exactly on the equations and methods presented in the literature part, the equations describing the unit models are not repeated in the experimental part. However, the elementary energy balance calculation theory is presented in the literature part, the simulator does not include energy balancing, which is the subject of later developments.

The accuracy of the developed simulator is evaluated using three case studies. The copper heap leaching case study is based on real plant

data and illustrates the dynamic simulation capabilities of the simulator. Two steady-state material balance calculation examples illustrate the accuracy of the solution algorithms under several different conditions. The steady state case studies are based on textbooks, and the calculated results are compared with those obtained for the same flowsheets using two commercial simulation software packages.

7.2 Thesis abstract for the Master of Science

7.2.1 Chemistry

Monitoring of an Dearomatization Process

Bergman, Samuli

Early detection and identification of abnormal and undesired process states are essential requirements for safe and reliable processes. This helps to reduce the amount of production losses during abnormal events. The aim of this thesis was to study different fault detection and process monitoring methods applied in the chemical process industry and to compare the performance of these methods in monitoring an industrial dearomatization process.

In the literature survey part of this study, different methods used for monitoring and fault diagnosis of chemical processes are discussed. Artificial neural networks, fuzzy logic and statistical multivariate methods are replacing the quantitative causal models that have traditionally been used for process monitoring.

In the experimental part of the study, the performance of Kohonen self-organizing maps and statistical multivariate methods, principal component analysis (PCA) and partial least squares (PLS), in monitoring a dearomatization process are compared.

The data that were used in constructing the monitoring models were collected using a dynamic process simulator. The simulator model was modified to correspond to an industrial dearomatization process. Both normal state and different fault conditions were simulated. The process phenomena that were selected for simulation were an internal leakage in a heat exchanger, fouling of a heat exchanger and channeling of the catalyst.

The best PLS-model had six input and four output variables. The model was able to detect 53 percent of leakage cases, six percent of fouling cases and 69 percent of channeling cases as abnormal events. The advantage of the PLS-method is its ability to detect even novel faults.

The self-organizing maps were constructed separately for each abnormal state. The channeling of the catalyst was identified most reliably. The principal component pre-processed map was able to identify 94.5 percent of the channeling cases. The pre-processed map trained for leakage was able to identify 78 percent of the leakage cases. The detection of fouling was unreliable, since only 42 percent of the fouling cases were identified. The advantage of the self-organizing maps is that they are easy to use, since the map with colored neurons is very visual. The principal component pre-processing improves the maps' ability to classify process states.

The variables have a significant effect on the performance of the models. The variables should be selected based on both principal component analysis and process knowledge. Constructing computational variables that describe the monitored process phenomena is of great importance

Instrumentation audit of sugar manufacturing process

Forsell, Marko

In this thesis the generally used measurement techniques in sugar plants are explored. Also, the physical and chemical properties of sugars and polyols are studied. The unit processes of sugar manufacture are introduced. The objective of this thesis is to build a comprehensive discourse about the measurement techniques and why these techniques can be utilized in sugar plants. The chemical phenomena that occur in the processes can be understood on the basis of the properties of the components.

The literature part of the thesis reviews the characteristic properties of saccharose, glucose, fructose, xylose, xylitol and lactitol. The chemical background of the chromatographic separation, the evaporation crystallation and the hydrogenation as unit processes of sugar manufacture are examined. Refractometry, polarimetry, pH, density, conductivity, mass flow and volume flow measurement are introduced here. Of infrared applications, FTIR, NIR and Raman spectroscopies are studied in more detail.

In the applied part of the thesis, refractometers, a density meter and a radioactive density gauge were tested. The tests were carried out in the chromatographic separation pilot plant in Kantvik (Finland) and in the xylose production plant in the crystallation process in Lenzing (Austria). In the separation pilot plant, the meters were tested with different feed solutions and different parameters. The meters are compared to the reference values measured in the laboratory. Also, the correlation functions based on the mathematical least square method is developed.

Based on the results from the tests, decision-making concerning the measurement instruments for different applications in future projects will be easier. In the betaine solution separation process, the density-based dry substance meters do not operate properly. The refractometer is more stable and operates more accurately in betaine separation. With impure molasses solution, the prism of the refractometer can become dirty and therefore cause inaccuracy in the measurement. In the end of the crystallation process, the efficiency and operability of the refractometer and the radioactive density gauge decrease substantially.

Inference Methods in Industrial Fault Diagnostic

Grönbärj, Marko

The aim of this thesis was to develop an inference engine for a fault diagnosis system.

Fault diagnostics has recently been a subject of great interest and development. Knowledge can be transferred from process engineers to the fault diagnosis system by reasoning methods. With an expert system, faults can be diagnosed more accurately and maintenance is easy.

In the literature part, the basic structure and functions of a fault diagnosis system were introduced. Also, different rule-based inference methods were studied with examples from industrial applications.

In the experimental part, the structure of the fault diagnosis system was designed. The structure consists of a link between a database and the process, databases, a Kohonen map application, a symptom generator module and an inference engine. In this thesis, the inference engine, database link and symptom generator were implemented.

The inference engine developed was tested

with data collected from the steam dryer in the copper smelting process of Harjavalta Metals, and the knowledge of the process engineers was used. During testing, the system responded correctly to faults and normal conditions.

The rule-based inference used in the system succeeded in diagnosing faults and it is applicable to a structurally changing process.

Training material about turbocompressors and their control methods

Laiho, Emmi

Turbocompressors are used in process industry to raise the pressure of gas and to transport compressed gas. Because response times in compressor control need to be shorter than in normal process control, used control methods are different.

The purpose of this thesis was to prepare training material about turbocompressors and their control methods. The training material was intended for use of control room operators in the Porvoo refinery of Fortum Oil and Gas. The aim of the training is to improve the operators' independent initiative during abnormal process conditions.

In the literature survey, the construction, characteristics, control methods and operation of turbomachinery are studied. The principles of pedagogy are also discussed.

In the experimental part of the work, HTML and javascript based e-learning material was implemented. The material consists of text, pictures and animations. To apply and practise the subjects studied, there are also exercises at the end of every part.

The second part of the training is done with simulator. It focuses on improving the practical skills in operating the controls of turbomachinery. In this part, important operating commands are practised and their impacts on the simulator are observed.

The e-learning material and the simulator part were tested, and the test results are reported. The implemented training material meets the requirements set in advance and it received good feedback during the tests. In addition, the technology used in e-learning material was new and implementation will be used as a model for future training material in Porvoo refinery.

Control Strategies of the Continuous Pressurised Three Phase Separating Tank *Mustonen, Valtteri*

The continuous pressurised CTO-production (Crude Tall Oil) process developed in Rintekno Oy consists of a CSTR-type (Continuous Stirred Tank Reactor) acidification reactor and a separating tank. After the acidification reaction of solvent-bearing soap, the reaction mixture, which consists of three phases, is decanted. Raw tall oil is obtained as a product. The process has been implemented in the Kaukas research facilities of Sterol Technologies Oy. It has been noticed that the functioning of the process control is unsatisfactory. Control loops stabilise the controllable variables poorly and require the operator's constant supervision.

The objective of this thesis is to study the dynamics of the process and to improve the controls in such a way that the process is better controlled. The work aims to find basic control loops and a solution which would reduce the constant supervision of the process. One objective was also to assess the instrumentation of the process.

The literature part of the thesis reviews the physical phenomena of the pressurised CTO-production process and the theory of the separatory event. In this part the dynamic modelling and development methods of dynamic models of similar processes were examined. The literature concerning basic controls and higher-level controls of similar processes was studied.

In the applied part of the thesis, a dynamic model of the process was developed. Modelling was based on step tests. With the help of the dynamic model, optimal control loops and control parameters were selected. In the process control system, higher-level pressure control was developed to reduce routine setpoint value changes made by the process operator. An informative expert system was included in the system.

It was observed that the basic controls had already been selected in the optimal manner. The obstacle to functionality was process technical deficiencies. The higher-level pressure control reduces the setpoint value changes made by the process operators. It gives information to operate the process at the correct pressure. This information was previously unavailable. It was noticed that the information system contains the right elements to automate the process. To develop the information system into a process

supervision system more research is required. Suggestions for addition and change in the instrumentation of the process are given.

Simulation Study on the Control of the Bedand Furnace of a Fluidised Bed Boiler

Muurinen, Matti

Fluidised bed combustion has established itself as a method of solid fuel combustion, especially in small-scale plants. In view of process engineering, the good opportunities to use various kinds of fuels with a high efficiency can be regarded as one of the strengths of fluidised bed boilers. Also their simple structure can be regarded as another strength. Rapid and strong variations in the quality of fuels, however, put heavy demands on the control systems of the fluidised bed boiler. In order to be able to use fluidised bed boilers with as high efficiency as possible, also the control methods used in them shall be developed and various needs shall be taken into account, for example, in view of the optimisation of operating conditions.

The purpose of this study was to develop the automation of the furnace of a fluidised bed boiler to better take into account the quality variations of fuel and remote-control aspects. With better control of the furnace and the bed, the combustion conditions can be stabilised, the temperature fluctuations of the furnace can be balanced, and that way the power output can be stabilised. With active control of bed temperature, the available fuel selection can be expanded, operational safety improved and the amount of incombustible in the ash diminished. Until now, the operators have controlled the bed temperature manually with the aid of correction coefficients.

In the study, an adaptive control system of bed temperature based on a physical and chemical model was developed. The development of bed temperature in respect of control variables is very non-linear, and one of the sub-entities of the study was to compile a model describing the behaviour of bed temperature on the basis of literary research and existing data. Another sector of the study was the improvement of the functioning of the air distribution of the furnace and the stabilisation of combustion conditions. In the study, a control structure for the distribution of combustion airs was developed, based on the regulation of air coefficients

prevailing in the furnace, irrespective of the operating point or power level of the power plant. The calculation of air coefficients is carried out on the basis of steam circuit measurements, in which case the delays occurring in the flue gas analysis can be efficiently avoided. The standardisation of air coefficients is deemed to improve efficiency and diminish nitrogen oxide emissions.

The operation of developed control structures in fault situations was tested with APROS, which is a dynamic simulation environment that supports control design, developed in co-operation between Fortum and VTT, the Technical Research Centre of Finland. A previously verified model of fluidised bed boiler was used as the simulation model. On the basis of the simulation results, with the bed temperature control system, the bed temperature can be controlled automatically according to the wishes of the user, despite the strong non-linearity of the process. With the developed control system, the linearisation of the process response in various operating points was successful. With the new combustion air distribution, a faster and more accurate control result was reached on the basis of the simulation results.

The developed bed management system can be duplicated to different power plants moderately easily, and it can be added on top of the normal automation as a layer of its own. Due to this capacity, the introduction of the system does not involve great risks. The control structures developed on the basis of positive simulation results are tested in the next stage of the project in plant-scale tests.

Further development of the control concept will aim at the development of an algorithm that optimises the combustion conditions of a suitable furnace and testing it at an operational plant.

Control performance indexes in petrochemical plants

Nevalainen, Susanna

The purpose of this thesis was to develop indices to evaluate the performance of a model predictive controller. The aim is to distinguish between different situations that cause the deviation of controlled variables. In addition to a tuning problem, the deviation can result from a device fault, a poorly tuned lower level controller or restrictions in the process.

In the literature part, the performance indices

of SISO-controllers were studied and different ways of evaluating the performance of a model predictive controller were surveyed. Other methods used in performance evaluation were also studied.

In the experimental part, the control performance indices were developed and tested. Applications developed by Neste Engineering were used. The simulated process was a dearomatization unit named LARPO. The model predictive controller was implemented to control the quality of the product. Control performance calculations were implemented in the controller. In particular the applicability of the prediction training and automation design and testing purposes. Using this kind of connection between a full-scale DCS and a large simulation model requires, however, a large throughput from the data connection.

OPC (OLE for Process Control) is a widely used, component-based specification for communicating between numerous data sources in the automation and process control industries. This thesis will introduce the architectural issues that affect the performance of data exchange using the OPC standard. Detailed design issues that affect the throughput are also discussed.

A new OPC server for the dynamic process simulator, Apros, has been developed and performance tests have been carried out. The performance metrics of the new server are compared to those of the existing OPC server. This comparison shows the benefits of the new architectural approach. The results show that communication based on the OPC standard can offer sufficient data-transfer capacity for most dynamic process-simulation purposes.

Requirements for the optimized OPC client are given. Finally, new application areas that can be managed using the new, more effective data exchange techniques are discussed.

OPC data transfer in large-scale dynamic process simulation

Peltoniemi, Jyrki

Progress in the area of dynamic process simulation will bring about a need for an effective and easy way to configure data exchange between a simulator and co-operating applications. One important example of this need is the task of transferring data between a distributed control system (DCS) and a process simulator.

An integrated system, in which the DCS and simulator are connected, can be used for operator training and automation design and testing purposes. Using this kind of connection between a full-scale DCS and a large simulation model requires, however, a large throughput from the data connection.

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Requirements for the optimized OPC client are given. Finally, new application areas that can be managed using the new, more effective data exchange techniques are discussed.

Wireless Automation in Process Industries

Suhonen, Jori

This study was carried out in the Laboratory of Process Control and Automation at the Helsinki University of Technology. The aim of the study was to find out the current status and future trends of wireless automation in process industries.

In the literature part of the study several technologies used in wireless automation were discussed. Special weight was put on the discussion of the suitability of these technologies for process automation purposes. The technologies discussed include all the relevant network technologies, connection protocols as well as application development technologies used nowadays and in the near future. In addition several case studies were covered in the literature part. The case studies include many interesting and innovative applications using wireless automation technologies ranging from simple small-scale systems to entire communication systems of a factory.

The experimental part of the thesis was divided into two parts. In the first part a questionnaire study about wireless automation was carried out. Altogether 220 professionals of the automation industry answered the questionnaire. The questions covered wireless automation from several aspects and the results from the questionnaire study tell us how the respondents see the current status and future trends of wireless automation. We can conclude that the respondents strongly believe that in the future wireless technologies will be used more and more extensively for process automation purposes. In particular, the use of wireless automation in process monitoring and process control applications seems to be increasing rapidly.

In the second half of the experimental part a wireless test environment was built using Bluetooth and commercial GSM-network. The aim of the environment was to simulate a tank's communications structure far away from the backbone system. In the system Bluetooth was used for short-range communications between meters and an SMS gateway. SMS was then again used for long-range communications between the gateway and the backbone system.

Experiences gained from the test environment were encouraging. First of all the system seemed to work very well for the job and secondly the system was relatively easy to implement and to configure. The only small problem with the system was the use of SMS, which cannot be used in real-time meter reading applications. Using e.g. GPRS instead would solve this problem. In the future the environment will be used for educational and scientific purposes.

7.2.2 Pulp and paper

Profitability and cost model of paper machine operations

Dietrich, Maija

The aims of the thesis were to develop a cost and profitability model of three different paper grades in a paper mill and a profitability simulator of a paper mill.

In the literature survey part was studied different profitability and costing principles and methods in paper industry. The survey indicated that costs and profitability models in paper industry form three categories: combined process,

cost and profit models, cost and profit models developed by utilising process data and cost models developed on basis of realised costs and accounts (standard costing). A suitable method for modelling paper grade production costs was found. This method combined cybernetic standard costing, bottle-neck costing, activity based costing (ABC), which were extended with engineering approach such as mass balance calculations. Another possible method appeared to be developing a process model combined to a cost model.

In the experimental part cost and profitability model for three paper grades were developed in a case paper mill. In modelling the production process was divided into stock preparation, paper machine and finishing. In each sub process the dependency of resource consumptions on process variables were modelled either with statistical methods or deterministically. Energy consumptions in different process positions were calculated statistically and raw material consumptions deterministically according to recipes and mass balance calculations. In addition to financial key figures, key figures describing production efficiency were integrated into the model.

The development of profitability model of a paper mill included modelling dynamics of marketing, strategy processes, budgeting, production aspects, monetary process and analysis the results (profit and loss statement, balance sheet and key figures). The cost and profitability models of different paper grades were utilised as a part of production process. The modelling of a paper mill processes was carried out by first finding procedures from literature and then specifying and simplifying procedures to correspond real practises in paper industry utilising Delphi method. The simulator, KnowFinance Enterprise simulator was developed successfully.

The practical applicability and significance of the models developed in this study are obvious. Firstly, the developed tools can be used either in training or support for decision making at different mill levels. Secondly, the modelling framework developed in this study can be widely applied for other paper mills. Thirdly, the integration of key figures and data flow at different mill levels accurately describes the state of the company and the causal connections between various factors.

Measuring the rheological properties of surface sizes

Hafrén, Lena

The purpose of this work was to develop and test a rheometer suitable for the surface sizes used in the paper industry. The new rheometer is an improved version of the classical coaxial cylinder rheometer. Two sensors were developed, one for low viscosity size and one for higher viscosity values.

The theoretical part gives background information on rheology, existing rheometers and surface sizing.

In the experimental part, tests were made at a paper mill manufacturing surface-sized paper. The rheology of the sizes used in the production were tested, first with a Brookfield RVDV coaxial cylinder rheometer and then with the new rheometer. In the preliminary tests, a good sampling technique and rheological information about the sizes were obtained.

The actual tests were carried out by installing the new rheometer in a small-scale process with flow and temperature control. Size was added to the small-scale process and run at constant temperature and flow. The rheometer was tested on all the surface sizes used at the paper mill. The sizes were thermostated to different temperatures and diluted to different dry matter contents, since temperature and dry matter content are the most important parameters affecting rheology at the mill.

The measurement results showed that the new rheometer design worked well; it has good repeatability and resolution. The sensor for high viscosities works well within the shear rate region of 2000 - 5500 s⁻¹ for sizes with a viscosity of over 50 mPa·s. The sensor for low viscosities works in the shear rate region of 1000 - 7000 s⁻¹ and for viscosities of 1 - 175 mPa·s. A rheological phenomenon was found; the high viscosity sizes exhibit shear thickening behavior in high shear rate regions.

The new rheometer with the two sensors seems to function correctly and will be of benefit in the paper industry when preparing surface sizes, and later on, in other industries where on-line viscosity measurement is needed. Some R&D work will still be needed to turn the rheometer into a commercial product.

Development and start-up of ultrafiltration process control system in a publishing paper mill

Hevonoja, Tommi

Closing of water systems has been an important issue in the paper industry for quite a long time. Simultaneously, quality demands for process waters are increasing. This had led to the point when it is necessary to develop new, more efficient water purification methods. One of these methods is ultrafiltration. In theory, ultrafiltration is very efficient water purification method, but in the paper industry, demands for nearly full-automatic systems like CR-ultrafiltration are very high. These arguments led to investments especially in the process control system to be reliable regardless of possible changes in process dynamics.

The theory part of this Master's thesis includes an introduction to different kinds of membrane filtration methods and comparison of processes and process control differences. The theory part also considers ultrafiltration modeling and process start-up in literature.

The experimental part includes a description of the development of the Kirkniemi PM1 gasket water ultrafiltration system during process- and automation system planning, system testing, process startup and follow-up. Kirkniemi PM1's ultrafiltration system includes three CR1010/100 ultrafilters produced by Metso Raisio. PM1's system is the first of its kind in the world, which gave a good opportunity to design new process control methods. As well as tuning of control circuits; turbidity- and conductivity measuring problems and solutions are presented. Process optimization possibilities are considered in the last part of the work.

The basic structure of the control system was based on experiences with earlier CR-ultrafiltration systems. During system planning and development, many points needed functional changes and extra testing to become reliable. For example, time delays in sequences, functional orders, and rapidity of control circles were discerned to be such points. Reliability of sequences in the strongly dynamic ultrafiltration process was under special consideration. For this reason adaptive process control methods were developed for the system. As a result of process start-up and follow-up the conclusion was that it is possible to make automation of the ultrafiltration process reliable if enough is invested in system planning and start-up tests.

Simultaneously, the limited scope of automation to fix mechanical process problems was found.

Practical experiments were carried out on the functioning of turbidity measuring in the short- and long-term. Air bubbles produced in the ultrafiltration process were found to be one of the major problems in turbidity measuring. During this thesis, an adequate solution was designed, but concurrently both the real timing of measuring and independent measure for each filter was forfeited. In the longer follow-up period sliming of the measuring sensor became the main reliability problem. As a result of the examination turbidity measuring as a fault detector of ultrafiltration system was found to be questionable.

Uniformity of quality at Metsä-Botnia Ab's Kaskinen plant

Malmi, Timo

By the help of modeling the statistical multivariate methods provide an opportunity to study huge datamatrixes and to create monitoring systems for supporting the process control. Off-line models tell us about the interactions between the process variables and enable the study of disturbance state. The aim of this thesis was by off-line modeling to find the most important variables that in the fiber line create changes in brightness, tensile strength, elastic modulus and beating energy requirement.

In the literature part the statistical multivariate methods, principal component analysis (PCA) and partial least squares projections to latent structures (PLS) are considered. In addition to the theoretical study the applicability of the methods is analyzed from the viewpoint of process research. Three cases using the multivariate methods in pulp production are represented.

In the experimental part the fiber line of the Kaskinen pulp mill is modeled starting from cooking in order to find and analyze the most important variables that have an effect on the chosen quality variables of Birch- ECF pulp. The brightness study is carried out by dividing the brightening process in 5 steps and the strength quality study in two parts depending on the use of SiMo- activation chemical. PLS-DA models were made for the strength quality variables to detect the variables that exhibit the strongest discrimination power.

The brightness study showed that the brightnesses in D/O and E/O- stages modeled best because of their biggest variance. The most

important variables for brightness were the brightening chemical portions, washing efficiency, alkalinity in the cooking stage and the changes of pH and mass flow in the ozone stage.

The data for strength study was collected during 14 months. For tensile strength, elastic modulus and beating energy requirement several shared and separate central variables. The changes in tensile strength were strongly affected by cooking kappa number, pulp species, pulp consistency, pH of the water extract and the conductivity of VHL- condensate. The most important variables for elastic modulus were cooking kappa number, pulp species, pulp consistency, viscosity and the quality of NaOH used in oxygendelignification. Beating energy requirement was strongly affected by pH of the water extract, pulp species, conductivity of the washing waters and oxygen gas portion.

In connection with the results, oxidized NaOH and make-up NaOH were combined in oxygen delignification to smooth the quality of used NaOH. The goal of the cooking kappa number has been started to raise in order to improve the strength qualities of Birch- ECF pulp and cooking efficiency. It is recommended to pay more attention to the changes in the quality of washing waters and to maximize the washing periods in the evaporation department so as to control the conductivity of VHL- condensate. According to the results, by controlling pH of the water extract it is possible to affect the beating energy requirement and thus all the strength qualities of pulp.

Development of BCTMP mill simulation model and modelling of TMP refiner

Matinaho, Sami

The aim of this study was to plan a dynamic BCTMP mill simulation model and to model the refiner in an APMS simulation environment.

The CTMP process and the specialities of the modelled Joutseno BCTMP mill are studied. Furthermore, refiner operation and control as well as the refiner models in literature were discussed.

The BCTMP mill model was carried out as a three-level hierarchical model. The three levels are mill level, subprocess level and process component level. The refiner was modelled through the three basic phenomena selected: heat energy transition into pulp, dissolution of fiber and steam division. Both models were planned to meet the requirements of the new

sequential mass and energy balance solver of the APMS simulator.

The qualitative results of both models were reasonable, but the quantitative results cannot be analyzed until the model validation with real mill data is completed.

The BCTMP mill simulation model provides an excellent tool for research and training purposes in order to manage mill-wide mass and energy balances. The model gives an opportunity to train the mill users to understand the mill's heat technical potential in different operation conditions.

Simulating and analyzing the effects of refiner segments on TMP-process using a theoretical model

Näränen, Janne

In the thesis a simulation model, called JAMA model, was used to simulate the effects of the refiner segments on the process conditions and pulp quality. The main object of this master's thesis is to test how well the JAMA model can simulate the real thermomechanical pulping process, when refiner segment design parameters are changed. This was done by comparing the simulated process conditions with the measured ones. In addition to this another object is to clarify the mechanisms that cause the changes in the refiner process conditions and in pulp quality between different segments. This is done by using the basic physical terms given by the JAMA model.

In the literature survey part of this study, the thermomechanical pulping process is introduced. The effects of the refiner segments and other factors on the process conditions and on pulp quality are explained. Also the basic principles as well as the balance equations of the JAMA model are introduced.

A mill scale test runs were performed in order to test the model. The refiner segment design parameters, whose effects were experimented in this work, were: the bar and groove width ratio, bar height, taper (the length of the refining zone), selective groove and number and place of dams. The process conditions and pulp quality parameters were measured on every trial.

It turned out that the JAMA model can simulate the effect of certain segment geometries fairly well at the qualitative level. In these cases measured and simulated process conditions changed to the same direction, when segment design parameters were changed. This was

however depended on the segment design parameter in question. The effect of selective groove could not be simulated properly. In a quantitative level the simulations differed significantly from the measurements. Usually the changes were smaller in simulations compared to the measurements. One of the reasons for these differences was assumed to be the fact that in most cases the disc gaps used in simulations differed significantly from the real disc gaps. This was due to the weak correlation between power consumption and disc gap in the model.

There seemed to be five different factors (relationships), given by the JAMA model, that could explain the differences in pulp quality parameters between different trials. It was found that usually high strength properties of fiber and low light scattering coefficient were related with some of the following: low fiber pressure, low volume fraction of fiber, high proportion of abrasion work or the fact that the power consumption moved towards the outlet. It was also found that short theoretical residence time in different balance volumes, especially where most of the energy is used, could be the main reason for low energy consumption or low freeness value. Another reason for this could be high proportion of collision work. The correlations between these five explanatory factors and measured pulp properties were usually the same in a qualitative level in all trials, which improved the reliability of these findings. The credibility of these findings was however reduced because the differences in the pulp properties were relatively small between certain trials and there were also difficulties with some of the measurements. Also the fact that the JAMA model could not simulate the effect of different segment geometries properly in a quantitative level makes the conclusions somewhat unreliable. However as a result of this work, many new ideas and hypothesis were born, which may be useful, when designing new more efficient segments.

Applying remote diagnostic methods in service business

Petäjä, Janne

Remote support and remote diagnostics have recently been a subject of great interest and research. Remote support centers have been founded by companies offering maintenance services. These centers help companies to operate more efficiently and improve their service.

The aim on this work was to study possibilities

of applying power plant expert services, especially remote support services in the paper industry. The aim was also to think about possibilities of expert and remote support services and their marketing. In this work, remote support is expert help to a customer from a remote support center.

In the literature part, remote diagnostics as an expert service, power plant expert services and remote support services are considered. Also, expert service marketing and remote support service marketing are discussed on a general level.

During the work, power plant experts and experts of the company offering remote support services in the paper industry were interviewed. There were also discussions with experts working in paper mills. In the experimental part of the work, results of the interviews and valve monitoring application are presented.

On the basis of interviews, paper machine steam and condensate systems and TMP plant were found to be the most promising target for power plant expert services. In developing and marketing remote diagnostic services co-operation networks are found essential. It is also important that the real benefits of the service can be shown to customer.

Optimising Wet End Chemistry in Wallpaper Base Machine

Rönkkö, Kati

This Master's thesis deals with the wet end chemistry of the wallpaper machine PM3 of Kyro Board Mill. It is part of a project that aims to improve the retention of starch by making the chemical conditions more anionic by cutting down on cationic chemicals and raising the pH of circulation water, proportioning pulps and headbox.

In the literature survey part of this study, the main chemicals (starch, rosin size and alum) used in wallpaper making and their functions are introduced. Also, the measurement and control of pH and retention are discussed.

At first the aim was to concentrate on general observation of the chemistry, minimising the process changes and changing the wet end chemistry so that cationic chemicals will react better. pH control of circulation water and the machine chest enabled the pH to be raised in the proportioning pulp and to stabilise the pH changes. It was not possible to raise pH in the headbox when making simplex wallpaper. Due to the coated broke rich in calcium carbonate,

the pH rose more easily when making duplex wallpaper. Transferring the proportioning place of anionic starch in use, the desired results were not achieved.

In the next period, attempts were made to raise the pH in the headbox by partly replacing alum with sodium aluminate. The aims were not achieved. However, sodium aluminate seemed to improve the retention of anionic starch. Cationic starch did not have better retention in the trial than the anionic one. The use of fixing agent as affixing pitch and anionic trash did not seem to improve the retention of cationic starch. In summary: it does not seem possible to improve the retention of starches under the conditions of PM3. To reach Cobb targets, a lot of size and alum are proportioned so that the process pH is buffered to 3.8-4.4. Then there are no places on the fibres for cationic chemicals.

Typical retention levels for different paper grades were determined. It seemed that some grades had better retention when there was lower ash content in the headbox or a lower machine speed. Because PM3 is run strictly according to Cobb targets, correlation between retention and sizing was not found. When producing HS grades, larger amounts of alum and rosin size are used causing lower pH and also lower retention than other grades. The implementation of the Kajaani RMI analyser for online measurement of retention was included in the project. Because of the difficulty and unreliability of pH measurements, the main focus should be on equalisation of pH measurements.

Modeling the Technical Age of a Pulp Mill

Ylä-Jarkko, Olli

Technical age describes the overall technical state and competitiveness of a mill. Technical age increases over time and decreases as a result of rebuilds. The term is used for comparison of different mills and for the calculation of some specific performance indicators. The present calculation method divides the pulp mill into six sections and department-specific rebuilds into three categories. The objective was to create a new model in which the mill is divided into smaller sections each contributing to the technical age of the whole mill. In addition to the enhanced technical age calculation model, an objective was to create a mathematical model for evaluating the monetary value of the rebuild based on the technical information.

In the theoretical part of the thesis, modeling and the applications of modeling and simulation in the pulp and paper industry are presented. The investment behavior of the industry and the factors affecting rebuild decisions at mill level are also discussed. In addition, a pulp mill is described department-by-department and important performance indicators are discussed.

The empirical part of the study began by determining the investment cost structure of a pulp mill. The analysis was based on an investment calculation model used by the company and on pulp mill feasibility studies and implementation projects. Based on the investment cost structure, specific weighting coefficients for different rebuilds were determined using nonlinear optimization. The reduction in technical age can be calculated by multiplying the weighting coefficients. A model between the investment costs and reduction in technical age was also developed in the empirical part. Models were developed for the mill and for each department separately.

As a result, an application tool was developed for the use of the company. A new database with a user interface was created to store the data required by the calculation model. Next, a calculation program connected to the database, was developed. The application can be attached to the other applications used by the company.

The results of the study offer particular benefits for the preparation of competitiveness and comparative analyses. Because of incomplete raw data, the estimation of investment costs based on technical details contains factors causing uncertainty. However, the ultimate goals of the study were met.

7.2.3 Mining, mineral and metallurgy

On-line testing of a process monitoring system and analysis of results

Endén, Petri

The purpose of process monitoring is to detect abnormal process deviations. When developing faults are detected at an early stage, corrective actions can be performed and loss of quality or production can be avoided. The aim of this master's thesis was to study the theory of process monitoring and to test a process monitoring system developed by the Laboratory of Process Control and Automation.

The literature part focuses on presenting different process monitoring methods. Special attention is given to Kohonen self-organizing maps and their industrial applications. Statistical process control, principal component analysis and partial least squares are also described briefly. Neural network based applications for blast furnaces and automated machinery are presented as industrial-scale examples.

The experimental part focuses on testing results from the Harjavalta copper smelting process. The aim in process monitoring was to detect concentrate aggregations in the concentrate burner and dust aggregations in the waste heat boiler. Process data for the monitoring was collected from the end of June 2001 until the end of November 2001. Also, data was collected from the actions taken in faulty situations to bring the process back to its normal operational state. The latter data was used to mark the faulty situations into the process data.

Different maps with different variables were trained to monitor both phenomena. Principal component analysis was also applied to the process data. Maps with 8 variables were selected for the final testing period. Most of the variables were computational rather than direct process measurements. The monitoring of concentrate aggregations was rather successful, but with dust aggregations, only satisfactory results were obtained.

Due to the fact that both of the phenomena were very hard to monitor, it can be stated that overall good results were obtained. The small number of on-line measurements prevented accurate monitoring of the concentrate burner. In the case of the waste heat boiler, the lack of reliable fault data was the main cause for the results.

Mass Balance Algorithms for Reacting Systems and Strategies for Computer Simulation

Grau, Rodrico

The aim of this thesis was to design, implement, test and evaluate new calculation methods for handling steady-state mass balances for reacting systems. The implementation was effectuated in a novel process simulator developed at the Laboratory of Process Control and Automation.

In the first part of the study the main commercial process simulators are reviewed, and a complete description of two process simulators is given. These are used as estimation tools in the

experimental part of the study. The developed simulator is based on the sequential modular strategy, and the generic structure of the approach is presented. The literature study focuses on the fractional conversion strategy and on the key components method, which are approaches normally used for solving mass balances involving multiple chemical reactions. The implementation of these strategies in the reactor unit is described in the experimental part of the study.

The performance of the key components method is improved by using quadratic programming optimization. The simulator is tested and evaluated at the end of the experimental part. Three case studies are performed. In the acetaldehyde case study, the performance of the conversion methods and key components method is analyzed. The nitric and phosphoric acid production flowsheets are used to evaluate the precision and quality of the developed simulator when working with large flowsheets.

Rule based fault diagnosis system for industrial processes

Haavito, Sasa

The number of processes and amount process equipment an operator has to monitor have increased simultaneously with the growth of automation. A fault diagnosis system can detect abnormalities in the process at an early stage and support the operator in decision making. With the help of a fault diagnosis system, the operator has more time for recovery action before a threatening fault situation becomes so bad that it cannot be controlled anymore. In the literature part, design process for user interfaces and different kinds of visualization methods are introduced. Also, fault diagnosis methods are studied with industrial application examples. In the experimental part, a rule-based fault diagnosis system was designed and implemented. Also, a process interface for Outokumpu Harjavalta Metals Damatic XD- automation system and user interfaces for maintaining and operating were implemented. The fault diagnosis system implemented was tested on-line in the copper flash smelting process. If abnormalities in the process, based on heuristic rules, are detected, the fault diagnosis system gives expert advice for recovery operation. The rules are based on limit value checking of measurements, formulas and Kohonen maps.

Remote Support System for Pressure Filter — Data Acquisition and Technical Solutions on Data Security

Lipiäinen, Jouni

The aim of the thesis was to develop a cheap and reliable software application for a data acquisition system to a Larox pressure filter. The software will gather information about the operations of the pressure filter and this data will be stored in a database at Larox. The data is targeted to the needs of Larox maintenance services and the Larox research and development unit.

The tools of software development and the technologies of database management standards provided by Microsoft were examined in the thesis. The most common technologies for data security and their applications were studied in the theoretical part of the thesis. Also, the properties and applications of Windows CE operating system were evaluated.

A Windows CE based control panel acts as a user interface for Larox pressure filter. The data acquisition software was built on this operating system and it collected data from programmable logic control and stored the data on the control panel. The purpose of this system was to save data temporarily on the panel and communicate with and send the collected data to Larox database server via phone lines or an internet network.

As a result of the work, Windows CE was found to be a quite efficient operating system for software application developing and the needs of the process industry. Because of a lack of correctly functioning hardware, it was impossible to develop a fully mature software application. Nevertheless, the data collection, data storing and data transfer to a database were implemented successfully by using modified data cables and commercial software.

Effects of the XRF analyzer accuracy and sampling frequency on the control performance of flotation

Remes, Antti

The object of this thesis was to study the control performance of the flotation process as a function of the measurement accuracy and sampling frequency of an XRF analyzer. An additional aim was to determine how the economical viability of the copper dressing process depends on the quality of process control.

Control of the flotation process requires concentration measurements from several process lines. The XRF analyzer can be used to analyze the concentrations of slurry lines in a continuous cycle. The control performance depends on the analytical accuracy and sampling frequency of the concentration measurement. With a long cycle time, the state of the process changes before a new measurement becomes available. The XRF technique is based on x-ray fluorescence intensity. With shorter measurement times the statistical deviation of the computed x-ray pulses increases. In addition, the measurement accuracy depends on the concentration of the component to be measured from the slurry. The total error of measurement accuracy and sampling frequency can be minimized by optimizing the combination of measurement time and cycle time for each of the measurement lines.

In the literature part, the components of measurement accuracy and sampling and mathematical methods are studied. The theories of flotation, XRF technique and optimization of the flotation process were also briefly reviewed.

The experimental part was carried out by constructing a dynamic process model in the Matlab environment. The modelled process was the copper flotation circuit of the Pyhäsalmi mine. The Pyhäsalmi process and the Courier analyzer were first described. The components of the accuracy of XRF analysis were also classified according to Gy's theory. The model comprises a first order reaction equation and the grade-recovery -relationship estimated from the process data.

The total accuracy of the on-line XRF measurement with different measurement times and sampling frequencies was estimated by means of the process simulations. The optimal measurement times for concentrate, feed and tailings were determined as a function of sampling frequency. The optimal degree of filtering was also studied. The economical result of the process declines strongly when the sampling cycle is increased. The economical viability of the simulated Pyhäsalmi process corresponds to an almost uncontrolled process when sampling cycles longer than 40 min were applied.

The Intelligent Field Devices - a Part of Asset Management

Sihvo, Olli

This thesis describes the architecture of the Asset Management and the intelligent field devices. Especially the ABB frequency converter's capability to function as the part of the Asset Optimisation system has been examined. The aim of the study was investigate the possible benefits of the Asset Management for the intelligent field devices and define the frequency converter's required functions and features, which could be used by the Asset Optimisation or Asset Management applications. The thesis based on the several conference publications, fieldbus standards, and ABB industrial-IT standards. At the beginning of this thesis is defined the content of the term 'Asset Management'. The thesis defines an architecture model for the Asset Optimisation system. The ACS 600 frequency converter is taken under the more detailed examination and all its functions are divided according to the created model. Thesis defines the existing Asset Optimisation features of the frequency converter and also the basic Asset Optimisation requirements of the drives are listed. Maintenance is the main area of the effective Asset Management hence the lifetime estimation algorithms of the frequency converters have been under more detailed investigation. Especially the estimating methods for the useful lifetime of the drive were examined more detailed. Accuracy of the life time estimation algorithms was assessed to be the few months, which provide good estimation for the useful lifetime.

Development and Implementation of Control Strategy for Pulp Levels in a Series of Flotation Cells

Tiili, Otso

The aim of this thesis was to develop and implement a control strategy for pulp levels in a series of flotation cells.

Flotation is a very complex separation process for minerals. Pulp level in a cell is one of variables affecting the process. An industrial scale concentrator usually has cells connected in series. This leads to problematic level control due to interactions between control loops. The control performance of widely used separate PI-controllers has been noticed to be insufficient for this task.

In the literature part of the thesis, the flotation

process and the principles of the flotation control were studied. Also the most commonly used control strategies and their applications to level control reported in the literature are presented.

In the experimental part, different level control strategies were evaluated by means of value analysis. Control performance as well as aspects of usability, cost, marketing and hardware requirements were taken into consideration in the value analysis. On the basis of the results of the value analysis, a decoupling controller with on-line parameter estimation was chosen to the implementation. The prototype was implemented in the automation system of Outokumpu Mintec and was tested in simulations.

The simulations showed that the performance of the new decoupling controller was substantially better than the performance of the traditional PI-controller.

Utilization of Fieldbus Technology in Control and Information System of a Process Device

Timperi, Juha

The objective of this thesis was to build a fieldbus based automation system for a pilot flotation cell in the Laboratory of Process Control and Automation at HUT and to research the possibilities in utilizing digital fieldbus technology in device diagnostics. This thesis was done as a part of the Tekes-project "Embedded fault diagnostics in an intelligent flotation cell".

The goal was to build an automation system similar to the commercial Procon system. The main difference from the Procon system was utilization of a digital fieldbus instead of analog 4-20 mA signalling. An architecture that would be scaleable and as modular as possible was aimed for. Because the system was to be used for research on device diagnostics, the presence of "islands of automation" was not accepted. All the information from the field level was to be readable from the supervisory levels

In the literature part of the thesis, the architecture of the system that fulfils the criterion described above is discussed. Then the related interface standards are described; fieldbuses on the instrument level and OPC on the system level.

In the experimental part of the thesis, the structure of the automation system of the pilot flotation tank is described and the technologies

chosen are argued. Fieldbus technology was chosen to be Foundation Fieldbus because it is highly suitable for use in device diagnostics. The supervisory level communication mechanism was chosen to be OPC. During the thesis a Fidi diagnostics tool by the Technical Research Centre of Finland was also tested.

Because of the good experiences from the thesis, it can be claimed that Foundation Fieldbus and OPC form a good basis for device diagnostics.

On-line monitoring of process disturbances for the Outokumpu copper smelting process

Vermasvuori, Mikko

The aim of this thesis was to develop a fault diagnosis system that detects process disturbances and equipment malfunctions in the Outokumpu copper smelting process.

Fault diagnosis has gained growing interest among researchers during recent years. Early detection of abnormal process conditions increases safety and decreases process downtime and the amount of production that does not meet the quality criteria.

In the literature part, different fault diagnosis methods are described on a general level, and the Kohonen Self-Organizing Maps (SOM) in more detail. Two cases where SOMs are used in industrial fault diagnosis are described.

The experimental part begins with a description of the copper smelting process. After that, the structure of the designed fault diagnosis system is described. Training of the SOMs and their ability to perform classification of different process states is described in detail. The experimental part ends with a description of the rules used in the system and the test results gathered during testing at the Outokumpu Harjavalta copper smelter.

The fault diagnosis system was tested in Outokumpu's smelter in Harjavalta. Testing showed that the system structure worked and the SOMs and rules used gave satisfactory results.

The implemented fault diagnosis system can be used in different kinds of processes. Its most important capability is to detect process disturbances that are difficult to detect directly from measurement data. The prerequisite for using this system is that there is large amount of data including measurements from both normal and abnormal process states.

8. International activities

The main international activity the Laboratory of Process Control and Automation participated was IFAC MMM Workshop “ Future trends in automation in mineral and metal processing” which was held on the cruise ship M/S Silja Serenade between Helsinki and Stockholm, August 22-24, 2000.

The aim of the workshop was to provide researchers and engineers from industry and academic life with a platform for reporting recent developments in the newly emerging areas of technology and their potential applications to process automation. The technical programme consisted of a total 72 papers, previously selected from full draft papers. In attendance were 170 people from academia and industry representing 26 countries. The participants had also opportunity to make technical visits to Finnish plants which are in forefront of process automation; Outokumpu Zinc Plant, Kokkola; Rautaruukki Iron and Steel Plant, Raahе; Outokumpu Chromium Mine, Kemi and Outokumpu Stainless Steel Plant, Tornio.

The technical program also included six plenary talks given by invited leading experts in the field: Prof. Tom McAvoy (University of Maryland, USA) who represented a talk on *Intelligent “Control” Applications in the Process Industry*; Jaques McMullen Director of Metallurgy and Technology (Barrick Gold Corporation, Canada) who focused his talk on *Process Control Advance in Gold Processing*; Ryoichi Takahashi, Assistant General Manager of Corporate R&D (Sumitomo Metal industries Ltd, Japan) made a presentation with the title *Control Applications in Japanese Steel Industry*, and Martin Schlang (Siemens AG, Germany) addressed *Future Development in Neural Computation in Steel Processing*.

In September 2001 the Lab’s postgraduate students and the professor made a trip to Kyoto University where the seminar was held together with professor Araki’s postgraduates. After visiting the university the group participated the 10th IFAC MMM Symposium organized by the Division of Instrumentation, Control and System Engineering of the Iron and Steel Institute of Japan at Waseda University in Tokyo.

The lab’s students also participated in the triennial IFAC World Congress which was held in July 2002 in Barcelona. In connection with the Congress The Control Engineering Practice Paper Prize for 2001 -award was given for the article ‘Intelligent control system of an industrial lime kiln’ written by M.Sc. (Eng.) Mika Järvensivu, M.Sc. (Eng.) Kari Saari and professor Sirkka-Liisa Jämsä-Jounela.

In Barcelona The IFAC General Assembly nominated Prof. Sirkka-Liisa Jämsä-Jounela as the ordinary member of the IFAC Council. Professor Sirkka-Liisa Jämsä-Jounela was also nominated as Vice-Chair of the IFAC Technical Board. The term of office commenced with the General Assembly at the 15th Triennial World Congress (Barcelona, Spain, July 21-26,2002) and terminates with the General Assembly at the 16th IFAC World Congress in Prague, Czech Republic.

IFAC MMM Workshop “Future trends in automation in mineral and metal processing”



Director Jussi Asteljoki from Outokumpu Group, Corporate Management presented a talk on ' Role of Automation in Outokumpu Group Business '



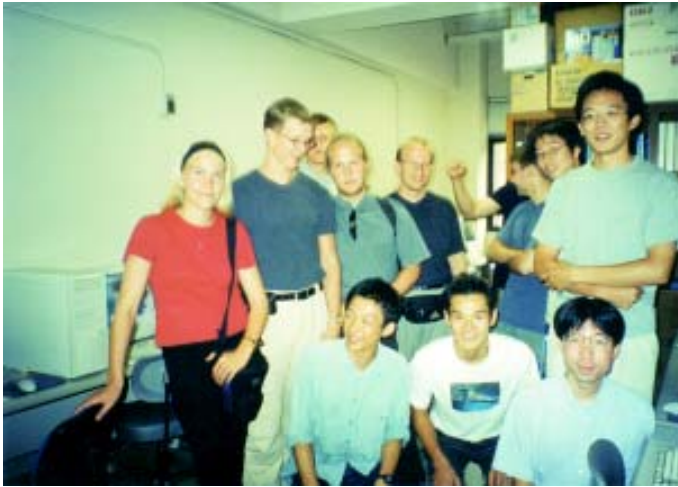
Director Veikko Heikkinen from Rautaruukki Group, presented a talk on ' Technological Challenges in Steel Industry '



The MMM TC members and their spouses spending socially time with discussions and amicable free time activities in Humaljärvi, Kirkkonummi

Professor Jämsä-Jounela, the evening's hostess together with MMM TC members. Dr. Günter Metzger and Dr. Ian Barker from South Africa, Professor Dominique Sauter from France and Professor Daniel Hodouin from Canada.





Visiting in Kyoto University. Students from Finland and Japan: Maija Dietrich, Sasa Haavisto, Otso Tiili, Petri Endén, Mikko Vermasvuori, Timo Rynnänen (actually only his hand), Juha Timperi and their Japanese colleagues.

Professors Araki and Hashimoto hosted dinner at a Japanese restaurant.



Celebrating Sasa Haavisto's and Juha Timperi's graduation. In picture from left Maija Dietrich, Otso Tiili, Juha Timperi, Timo Rynnänen, Professor Sirkka-Liisa Jämsä-Jounela, Petri Endén, Sasa Haavisto and Mikko Vermasvuori.



Professor Tom McAvoy (University of Maryland, USA) on the shore of a river in Lapland with his 10 kilos catch of salmon.

IFAC World Congress in Barcelona, July, 2002



M.Sc. (Eng.) Mika Järvensivu, M.Sc. (Eng) Kari Saari and Professor Sirkka-Liisa Jämsä-Jounela receiving 'The Control Engineering Practice Price for 2001'-award.

Mikko Vermasvuori, Petteri Kämpjärvi, Petri Endén and Kalle Halmevaara at Helsinki Airport ready to take off to Barcelona



8.1 Invited lectures, seminars and technical visits by academic staff

Jämsä-Jounela Sirkka-Liisa, D.Sc. (Tech.), Professor

4th IFAC Symposium on Fault Detection

Supervision and Safety for Chemical Processes, Budapest 14.-16.6.2000.

(Paper: Fault diagnosis and remote support system for the variable volume pressure filter)

28th Conference on Automation and

Telecommunication in Mines and Processing plants-roal and minerals, 14.-17.7.2000, Poland, Szczyrk Oikabd.

(Paper: Intelligent process monitoring system)

IFAC Workshop on Future Trends in Automation in Mineral and Metal Processing, Helsinki 22.-24.8.2000.

(Papers: State of the art and challenges in mineral processing control; Using principal component analysis and self-organizing map to estimate the physical quality of cathode copper; Fault diagnosis system for the Outokumpu flash smelting process; Fault diagnosis system for the variable volume pressure filter; State of art in copper hydrometallurgic processes control; Current status and future trends in the automation of mineral and metal processing)

32nd Annual Operator's Conference of the Canadian Mineral Processors, Ottawa 18-20.1.2000.

(Paper: Flotation process neural data analysis and on-line monitoring)

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Prosessien monitorointimenetelmät kemian teollisuudessa)

2001 American Control Conference (ACC), Arlington, Virginia, USA, June 25-27, 2001.

(Paper: Industrial applications of the intelligent fault diagnosis system)

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Painesuodattimen

etävikadiagnostiikkajärjestelmä; Älykkäät mittalaitteet ja kenttäväylät prosessiautomaation opetus- ja tutkimuskäytössä; Hierarchically structured intelligent system for stabilizing and optimizing industrial processes; Outokummun liekkisulatusprosessin vikadiagnostiikkajärjestelmä; Vaahdotuskennojen pinnansäätö; Outokummun liekkisulatusprosessin vikadiagnostiikkajärjestelmä; Prosessien monitorointimenetelmät kemian teollisuudessa)

10th IFAC Symposium on Automation in Mining Mineral and Metal processing (MMM2001), September 4-9, 2001, Tokyo, Japan.

(Papers: Fault diagnosis system for the Outokumpu flash smelting process; Evaluation of future automation trends in control and fault diagnostics of a flotation plant; Control of pulp levels in flotation cells; Current status and future trends in the automation of mineral and metal processing)

2001 TMS Annual Meeting, New Orleans, Louisiana, February 11-15, 2001, USA. (Paper: Fault diagnosis system for the Outokumpu flash smelting process)

b'02 Barcelona 2002 IFAC 15th World Congress, Barcelona, Spain July 21-26, 2002.

(Papers: Fault diagnosis system for the Outokumpu flash smelting process; Monitoring of an industrial dearomatisation process; Level control strategies for flotation cells; A toolbox for on-line process monitoring with some industrial applications; Evaluation of level control performance)

IASTED International Conference, Cancun, Mexico, May 20-22, 2002.

(Paper: Effects of automation and information technologies on process control education)

Hauksdóttir Anna Soffia

b'02 Barcelona 2002 IFAC 15th World Congress, Barcelona, Spain, July 21-26, 2002.

(Paper: A decoupling grinding circuit control system)

Bergman Samuli

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Prosessien monitorointimenetelmät kemian teollisuudessa)

b'02 Barcelona 2002 IFAC 15th World Congress, Barcelona, Spain, July 21-26, 2002.

(Paper: Monitoring of an industrial dearomatisation process)

Dietrich Maija

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Vaahdotuskennojen pinnansäätö)

10th IFAC Symposium on automation in mining, mineral and metal processing (MMM2001), September 4-9, 2001, Tokyo, Japan.

(Paper: Control of pulp levels in flotation cells)

Endén Petri

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Outokummun liekkisulatusprosessin vikadiagnostiikkajärjestelmä)

10th IFAC Symposium on automation in mining, mineral and metal processing (MMM2001), Tokyo, Japan, September 4-6, 2001.

(Paper: Fault diagnosis system for the Outokumpu flash smelting process)

b'02 Barcelona 2002 IFAC 15th World Congress, Barcelona, Spain, July 21-26, 2002.

(Paper: A toolbox for on-line process monitoring with some industrial applications)

Haavisto Sasa

2001 American Control Conference (ACC), Arlington, Virginia, USA, June 25-27, 2001.

(Paper: Industrial applications of the intelligent fault diagnosis system)

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Outokummun liekkisulatusprosessin vikadiagnostiikkajärjestelmä)

10th IFAC Symposium on automation in mining, mineral and metal processing (MMM2001), Tokyo, Japan, September 4-6, 2001.

(Paper: Fault diagnosis system for the Outokumpu flash smelting process)

b'02 Barcelona 2002 IFAC 15th World Congress, Barcelona, Spain, July 21-26, 2002.

(Paper: A toolbox for on-line process monitoring with some industrial applications)

Halmevaara Kalle

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Vaahdotuskennojen pinnansäätö)

10th IFAC Symposium on automation in mining, mineral and metal processing (MMM2001), Tokyo, Japan, September 4-6, 2001.

(Paper: Control of pulp levels in flotation cells)

b'02 Barcelona 2002 IFAC 15th World Congress, Barcelona, Spain, July 21-26, 2002.

(Paper: Evaluation of level control performance)

Järvensivu Mika, M.Sc. (Tech.), Researcher
GUS'00 (Gensym Users Society Meeting), Barcelona 12-14 April, 2000.

(Paper: Hierarchically structured intelligent system for stabilizing and Optimizing industrial processes)

Automaatio 2001 Seminaaripäivät, Automaatio verkostuvassa maailmassa, Helsingin Messukeskus, 4.-6.9.2001.

(Paper: Hierarchically structured intelligent system for stabilizing and optimizing industrial processes)

Kuitunen Tatu, M.Sc. (Tech.), Researcher
4th IFAC Symposium on Fault Detection

Supervision and Safety for Technical Processes, Budapest 14-16.6.2000.

(Paper: Fault diagnosis and remote support system for the variable volume pressure filter)

IFAC Workshop on Future Trends in Automation

in Mineral and Metal Processing,
Helsinki 22-24.8.2000.
(Paper: Fault diagnosis system for the
variable volume pressure filter)

**Kämpe Jerri, M.Sc. (Tech.), Laboratory
Manager**

- 4th IFAC Symposium on Fault Detection
Supervision and Safety for Technical
Processes*, Budapest 14.-16.6.2000
(Paper: Fault diagnosis and remote
support system for the variable volume
pressure filter)
- IFAC Workshop on Future Trends in Automation
in Mineral and Metal Processing*,
Helsinki 22-24.8.2000.
(Paper: Fault diagnosis system for the
variable volume pressure filter)
- 2001 American Control Conference (ACC)*,
Arlington, Virginia, USA, June 25-27,
2001.
(Paper: Industrial applications of the
intelligent fault diagnosis system)
- Automaatio 2001 Seminaaripäivät, Automaatio
verkostuvassa maailmassa*, Helsingin
Messukeskus, 4.-6.9.2001.
(Papers: Painesuodattimen
etävikadiagnostiikkajärjestelmä; Älykkäät
mittalaitteet ja kenttäväylät
prosessiautomaation opetus- ja
tutkimuskäytössä)
- 10th IFAC Symposium on automation in
mining, mineral and metal processing
(MMM2001)*, September 4-9, 2001,
Tokyo, Japan.
(Paper: Remote support system for a
pressure filter)
- IASTED International Conference*, Cancun,
Mexico, May 20-22, 2002.
(Paper: Effects of automation and
information technologies on process
control education)

Kämpjärvi Petteri

- Automaatio 2001 Seminaaripäivät, Automaatio
verkostuvassa maailmassa*, Helsingin
Messukeskus, 4.-6.9.2001.
(Paper: Vaahdotuskennojen pinnansäätö)
- b'02 Barcelona 2002 IFAC 15th World
Congress*, Barcelona, Spain, July 21-26,
2002.
(Paper: Level control strategies for
flotation cells)

Poikonen Risto

- Automaatio 2001 Seminaaripäivät, Automaatio
verkostuvassa maailmassa*, Helsingin
Messukeskus, 4.-6.9.2001.
(Paper: Älykkäät mittalaitteet ja
kenttäväylät prosessiautomaation opetus-
ja tutkimuskäytössä)
- b'02 Barcelona 2002 IFAC 15th World
Congress*, Barcelona, Spain, July 21-26,
2002.
(Paper: Evaluation of level control
performance)

Tiili Otso

- Automaatio 2001 Seminaaripäivät, Automaatio
verkostuvassa maailmassa*, Helsingin
Messukeskus, 4.-6.9.2001.
(Paper: Vaahdotuskennojen pinnansäätö)
- 10th IFAC Symposium on automation in
mining, mineral and metal processing
(MMM2001)*, September 4-9, 2001,
Tokyo, Japan.
(Paper: Control of pulp levels in
flotation cells)

Timperi Juha

- Automaatio 2001 Seminaaripäivät, Automaatio
verkostuvassa maailmassa*, Helsingin
Messukeskus, 4.-6.9.2001.
(Paper: Älykkäät mittalaitteet ja
kenttäväylät prosessiautomaation opetus-
ja tutkimuskäytössä)
- 10th IFAC Symposium on automation in
mining, mineral and metal processing
(MMM2001)*, September 4-9, 2001,
Tokyo, Japan.
(Paper: Evaluation of future automation
trends in control and fault diagnostics of
a flotation plant)

Vermasvuori Mikko

- 10th IFAC Symposium on automation in
mining, mineral and metal processing
(MMM2001)*, Tokyo, Japan, September
4-6, 2001.
(Paper: Fault diagnosis system for the
Outokumpu flash smelting process)
- b'02 Barcelona 2002 IFAC 15th World
Congress*, Barcelona, Spain, July 21-26,
2002.
(Paper: A toolbox for on-line process
monitoring with some industrial
applications)

8.2 Other activities

A trip to
Suomenlinna in
June 2002



Major students at the Laboratory
free time party at UPM
Kymmene's headquarters...

..and Tai Chi



9. Publications

9.1 Books

Jämsä-Jounela, S-L.(Ed.), Vapaavuori, E.(Ed.), *Proceedings of the IFAC Workshop on Future Trends in Automation in Metal and Mineral Processing*, Elsevier, London 2001, 495 p.

9.2 Articles in Scientific Journals

Mc Avoy, T., Jämsä-Jounela, S-L., Patton, R., Perrier, M., Weber, H., Georgakis, C., Milestone Report for area 7 Industrial Applications, *Control Engineering Practice* (2003) (in print).

Jämsä-Jounela, S-L, Dietrich, M., Halmevaara, K., Tiili, O., Control of pulp levels in flotation cells, *Control Engineering Practice* 11 (2003) 73-81.

Jämsä-Jounela, S-L, Vermasvuori, M., Endén, P., Haavisto, S., A process monitoring system based on the Kohonen selforganizing maps, *Control Engineering practice* 11 (2003) 83-92.

Järvensivu M., Juuso E. and Ahava O., Intelligent control of a rotary kiln fired with producer gas generated from biomass, *Engineering Applications of Artificial Intelligence*, Vol 14 (2001) No. 5 pp. 629-653.

Jämsä-Jounela, S-L., Current status and future trends in the automation of mineral and metal processing , *Control Engineering Practice* 9 (9) (2001) pp. 1021-1035.

Hodouin, D., Jämsä-Jounela, S-L., Carvalho, M.T., Bergh, L., State of the art and challenges in mineral processing control, *Control Engineering Practice* 9 (2001) pp. 995-1005.

Bergh, L., Jämsä-Jounela, S-L., Hodouin, D., State of art in copper hydrometallurgic processes control, *Control Engineering Practice* 9 (2001) pp. 1007-1012.

Järvensivu M., Saari K. and Jämsä-Jounela S.-L., Intelligent control system of an industrial lime kiln process, *Control Engineering Practice*, 9 (2001) pp. 589-606.

Järvensivu M., Jämsä-Jounela S.-L. and Ahava O., Intelligent control system for ensuring low emission levels and heat losses while maximizing lime kiln production, *Tappi Journal*.

Jämsä-Jounela, S-L. Oja, M., Modelling module of the intelligent control system for the variable volume pressure filter, *Filtration & Separation*, 37 (2000) No 2, pp. 39-49.

Laine, S., Pulkkinen, K., Jämsä-Jounela, S-L., On-line determination of the concentrator feed type at Outokumpu Hitura mine, *Mineral Engineering* 13 (2000) No. 8-9, pp. 881-895.

Danielson, R., Järvensivu, M., Sophisticated and complete IT solutions for pulp and paper industry, *Nordicum Scandinavian Business Magazine*, 3-4 (2000), 3 sivua.

Järvensivu, M., Mäenpää, T., Jämsä-Jounela, S-L., Saari, K., Field survey of the reduced- sulfur emissions from a modern Finnish pulp mill, *Environmental Progress* 19 (2000) No 3, 147-156.

9.3 Articles in Conference proceedings (refereed)

2002

Jämsä-Jounela, S-L., Kesti, A., Vermasvuori, M., Rynnänen, T., Endén, P., Kämppe, J., An intelligent control system for a pressure filter, Proceedings of IEEE International symposium 'Intelligent systems', Methodology, Models, Applications in Emerging Technologies, Bulgaria., September 10-12, 2002.

Vermasvuori, M., Endén, P., Haavisto, S., Jämsä-Jounela, S-L., The use of Kohonen Self -organizing map in process monitoring, Proceedings of IEEE International symposium 'Intelligent systems', Methodology, Models, Applications in Emerging Technologies, Bulgaria., September 10-12, 2002.

- Jämsä-Jounela, S-L., Poikonen, R., Halmevaara, K., Evaluation of level control performance, *Proceedings of b'02 Barcelona 2002 IFAC 15th World Congress*, July 21-26, 2002, Barcelona, Spain (CD).
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