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OF TECHNOLOGY

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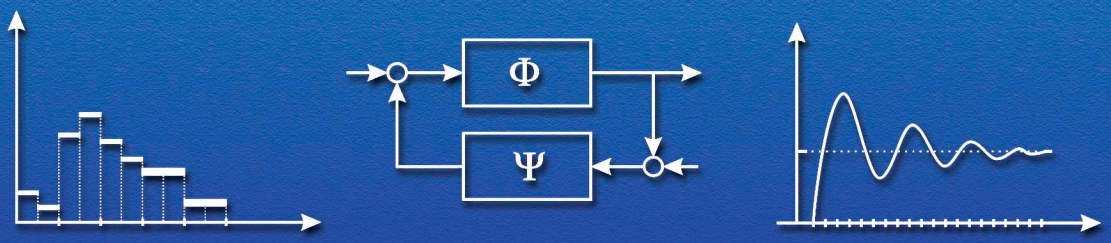

Institute of Automatic Control

Faculty of Automatic Control, Electronic and Computer Science

ACTIVITY REPORT 2003 2004

SILESIAN UNIVERSITY OF TECHNOLOGY

**FACULTY OF AUTOMATIC CONTROL,
ELECTRONICS AND COMPUTER SCIENCE**

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OF AUTOMATIC CONTROL

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Activity Report
2003-2004

Gliwice, May 2005

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Contents

GENERAL INFORMATION

The Institute of Automatic Control was founded on 1 October 1977, as a result of fusion of several groups at the Faculty of Automatic Control at the Silesian University of Technology. Currently the Institute of Automatic Control is one of the three institutes constituting the Faculty of Automatic Control, Electronics and Computer Science. The Institute members are involved in teaching of more than 1000 students from several study specialisations. General research directions of the Institute involve automatic control as well as modelling and analysis of systems and signals.

Research and teaching activities of the Institute are headed and coordinated by the Board of Directors including the following members:

Professor Ryszard Gessing	- Director, Head of the Institute,
Professor Jerzy Klamka	- Vice-director for Teaching,
Professor Mieczysław Metzger	- Vice-director for Research.

The following professors are members of the Institute of Automatic Control:

(For E-mail adresses see biographical sketches)

Adam Czornik	- associate professor,
Marian Błachuta	- professor,
Zdzisław Duda	- professor,
Jarosław Figwer	- professor,
Jerzy Frączek	- full and titular professor,
Ryszard Gessing	- full-titular professor,
Marek Kimmel	- titular professor,
Jerzy Klamka	- full and titular professor,
Reginald Krzyżanowski	- associate professor (till 1.10.2003),
Mieczysław Metzger	- full and titular professor,
Antoni Niederliński	- full-titular professor,
Janusz Piotrowski	- full and titular professor,
Andrzej Polański	- professor,
Andrzej Świerniak	- full and titular professor,
Zdzisław Trybalski	- full-titular professor,

Stanisław Waluś	- associate professor,
Konrad Wojciechowski	- titular professor (till 1.10.2004),
Mirosław Zaborowski	- professor (till 1.10.2004).

Central administration of the Institute:

Elżbieta Gajda, B.Sc.	- administrative manager,
Henryk Jakubiec, M.Sc.	- service for research equipment,
Elżbieta Król, M.Sc.	- service for research contracts and grants,
Marzena Schab, M.Sc.	- engineer.

The Institute of Automatic Control is well equipped for research and teaching, much of the equipment having been purchased in recent years. Computer basis of research/teaching includes over 150 personal workstations, most of them setup in reach hardware configuration. There are also several automation oriented, professionally equipped, research/laboratory stations.

Structure and staff

Research and teaching activities were conducted (till 30.09.2004) in 5 working groups at the Institute of Automatic Control: Since 1.10.2004 a new structure of the Institute has been implemented. It will be presented in a separate section.

The structure until 30.09.2004:

*** Control Theory Group**

Head:

Ryszard Gessing, M.Sc., Ph.D., D. Sc., full-titular professor.

Members:

Marek Kimmel, M.Sc., Ph.D., D. Sc., titular professor,
Andrzej Świerniak, M.Sc., Ph.D., D. Sc., full and titular professor,
Konrad Wojciechowski, M.Sc., Ph.D., D. Sc., titular professor,
Adam Czornik, M.Sc., Ph.D., D.Sc., associate professor,
Marian Błachuta, M.Sc., Ph.D., D.Sc., professor,
Zdzisław Duda, M.Sc., Ph.D., D.Sc., professor,
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Zygmunt Kuś, M.Sc., Ph.D., assistant professor,
Aleksander Nawrat, M.Sc., Ph.D., assistant professor
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Bogdan Smołka, M.Sc. Ph.D., assistant professor,
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Zbigniew Starosolski, M.Sc., Ph.D., assistant professor,
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Artur Bal, M.Sc., Ph.D. student,
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Rafał Grygiel, M.Sc., Ph.D. student,
Krzysztof Jaskot, M.Sc., Ph.D. student,
Roman Jamorski, M.Sc., Ph.D. student,
Marcin Pacholczyk, M.Sc., Ph.D. student,
Krzysztof Skrzypczyk, M.Sc., Ph.D. student,

Jarosław Homa, technician,
Jan Skrzyniarz, technician,
Mirosława Żywiec, technician.

*** Industrial Control Group**

Head:

Antoni Niederliński, M.Sc., Ph.D., D. Sc., full-titular professor.

Members:

Jerzy Klamka, M.Sc., Ph.D., D. Sc., full and titular professor
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Ewa Bielińska, M.Sc., Ph.D., assistant professor,
Dariusz Bismor, M. Sc., Ph.D., assistant professor,
Ryszard Jakuszewski, M.Sc., Ph.D., assistant professor,
Jerzy Kasprzyk, M.Sc., Ph.D., assistant professor,
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Małgorzata Michalczyk, M.Sc., Ph.D., assistant professor,
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Janusz Wyrwał, M.Sc., Ph.D., assistant professor,
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Mariusz Stasik, M.Sc., Ph.D. student,
Marek Szczepański, M.Sc., Ph.D. student,

Dariusz Sitko, M.Sc. engineer,
Edward Marchewka, technician,
Anna Sas, technician.

*** Control Systems and Control Instrumentation Group**

Head:

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Zdzisław Trybalski, M.Sc., Ph.D., D.Sc., full-titular professor, (half-time)
Reginald Krzyżanowski, M.Sc., Ph.D., associate professor, (till 1.10.2003)
Jacek Czeczot, M.Sc., Ph.D., assistant professor,
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Przemysław Plesowicz, M.Sc., Ph.D. student,

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Małgorzata Jaskólska, technician,
Klaudiusz Szołtys, technician.

*** Measurement Systems Group**

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Witold Ilewicz, M. Sc., Ph.D., assistant professor,
Andrzej Marcyniuk, M.Sc., Ph.D., assistant professor, (half-time)
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Janusz Żelezik, M.Sc., Ph.D., assistant professor,
Dariusz Buchczik, M. Sc., Ph.D. student,
Sebastian Budzan, M.Sc., Ph.D. student,
Tomasz Grychowski, M.Sc., Ph.D. student,
Andrzej Kozyra, M. Sc., Ph.D. student,
Alicja Wiora, M.Sc., Ph.D. student,
Józef Wiora, M.Sc., Ph.D. student,

Barbara Kochowska, technician,
Piotr Kotowicz, technician,
Roman Rakoczy, technician,
Mirosław Wardal, technician.

*** Robotics and Discrete Events Automation Group**

Head:

Mirosław Zaborowski, M.Sc., Ph.D., D. Sc., professor.

Members:

Damian Bereska, M.Sc., Ph.D., assistant professor,
Zbigniew Bortliczek, M.Sc., Ph.D., assistant professor,
Waldemar Grzechca, M.Sc., Ph.D., assistant professor,
Mieczysław Jagodziński, M. Sc., Ph.D. assistant professor,
Henryk Palus, M.Sc., Ph.D., assistant professor,
Tadeusz Szkodny, M.Sc., Ph.D., assistant professor,
Henryk Palus, M.Sc., Ph.D., assistant professor,
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Aleksander Staszulonek, M.Sc., Ph.D., assistant professor,
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Artur Babiarz, M. Sc., Ph.D. student,
Andrzej Czarnecki, M. Sc., Ph.D. student,
Marcin Heczko, M.Sc., Ph.D. student,
Maciej Kiwer, M.Sc., Ph.D. student,
Tomasz Primke, M.Sc., Ph.D. student,

Elżbieta Król, M. Sc., engineer,
Andrzej Fortuna, M. Sc., engineer (half-time),
Aleksandra Szczerbik, M.Sc., engineer.

New educational enterprises

Based on the two decades of research effort in biotechnology (in the bioinformatics lead by professor Andrzej Świerniak as well as in industrial biotechnology lead by professor Mieczysław Metzger) two important educational enterprises have been undertaken. The first one started in the fall 2003 involves new courses in Information Processing and Control in Biotechnology for students in Automatic Control and Robotics. The second one is interdepartmental study in Biotechnology initiated by three Faculties: The Faculty of Automatic Control, Electronics and Computer Science, The Faculty of Chemistry and The Faculty of Environmental and Energy Engineering. Our Faculty is responsible for specialization Bioinformatics for which enrollment will start in the fall 2005.

CONTROL THEORY GROUP

INFORMATION ABOUT RESEARCH ACTIVITIES

Research activities of the Control Theory Group include a wide variety of research projects of both theoretical and applied character. Topics of research are concentrated in three main directions: control and optimization theory, image processing and pattern recognition and biomathematical modeling.

CONTROL AND OPTIMIZATION THEORY

Linear – quadratic regulator with output feedback

R. Gessing

Augmented and minimal realization state space models are proposed for direct implementation of the discrete-time linear-quadratic regulator (DLQR) with measured not all the state variables but only the output of the plant. Both the models are related by means of original transformation with a rectangular matrix. Using this transformation it is shown that the resulting closed-loop (CL) system with dynamic output feedback regulator (DOFR) has the same stable roots of its characteristic equation as the CL system with state feedback and DLQR; the additional zero roots of the first CL system generated by DOFR do not change its properties, essentially. It is also shown that the CL system with DOFR realizes the optimal control with feedback from an augmented state, resulting from solving an appropriate DLQR problem. By appropriate choice of the state weighting matrix in the performance index, it is possible to obtain a partial pole placement of the CL system. The internal model of disturbances included to the augmented plant improves the quality of control. The researches concern also the continuous-time as well as multivariable systems.

The properties of the observer based LQ regulator are also researched. It is shown that this regulator is optimal for adequate initial condition of the observer. The latter

statement concerns both continuous-time and discrete-time systems. The case of nonadequate initial conditions is also researched.

Descriptor Versus State Space Models

R. Gessing , A. Czornik

Mutual relation between descriptor and state space models are investigated. It is shown that a descriptor system under the condition of impulse controllability, may be converted, by means of linear transformations, to a system described in a state space and composed of state and output equations. The transformations determine one to one correspondence between the solutions of both the systems. It is noted that the control in a feedback form may not determine a unique solution of the descriptor system what is often overlooked in many previous papers. It is also shown that the LQ problem formulated in a descriptor space for the impulse observable system may be converted by means of linear transformations to the usual LQ problem formulated in the state space. It is stressed that the second problem may be regular even then, when the weighting matrix of the control, in the cost functional of the first problem, is singular. The proposed approach simplifies the calculations related to the LQ problem solution significantly. The conclusion is that while developing a model of a real system it is more reasonable to choose the state space model completed by some algebraic equations than a descriptor one.

Description, Analysis and Design of Discrete-Time Systems Using Continuous-Time Methods

R. Gessing, M. Błachuta

At present most of the controllers are realized using microprocessors working mostly at high sampling frequencies. Application of the Z-transform approach to the synthesis with such controllers is connected with some difficulties. Therefore, the researches concern the application of the continuous-time methods for their description and design. One variable, as well as multivariable systems can be treated in this manner. Especially in the multivariable systems with controllers having different sampling periods the proposed method is useful since in that case there are difficulties in designing.

Sliding mode control with decreased chattering effect

R. Gessing

The idea of the system with sliding mode control and adaptation of the switched *Max-Min* amplitudes of the relay output is researched. The adaptation is possible owing to the observation that the sliding mode control is equivalent to bang-bang relay control of the sliding surface signal on the level zero. The rates of the increasing and decreasing parts of the sliding surface signal are used for independent adaptation of *Min* and *Max* values of the relay output, respectively. The adaptation causes that the difference (*Max-*

Min) is decreased and both the values tend to be placed symmetrically with respect to the needed value of the control. Owing to this the chattering effect appearing in the sliding control is decreased, significantly and the system remains very robust. Simplified model of the proposed solution is elaborated and the condition of stability is derived. The proposed approach is applied also for the systems with delay. To compensate the delay of the plant the Smith predictor is used.

An original compensator has been proposed to implement sliding mode control with decreased chattering for nonminimum phase plants. The idea of the compensator is similar as that of the Smith predictor. The difference is that the compensator from the point of view of control "changes" the plant from nonminimum phase to minimum phase one.

Modified Feedback Structure with Higher Order Derivatives in Regulator

R. Gessing

The idea of the researches is based on several facts. First, if the rational transfer function (TF) of open loop system has appropriately suited polynomial (*n-1)*-th order in numerator to the polynomial of *n*-th order in denominator then the closed loop system may be stable for very high gain. Second, this kind of open loop TF may be achieved by appropriate choice of the "dynamics" *Q(s)* of regulator, in which the described approximations of the first and if needed - higher order derivative are used. The performed simulations show that these approximations are implementable. Third, we propose the structure of feedback loop with the block diagram in which the high gain *k* and "dynamics" *Q(s)* of regulator are separated: *k* appears after the summing junction with set point *w* and *Q(s)* before it. Owing to this the proposed feedback structure implements model reference control with the reference model *1/Q(s)*. The proposed structure is *usually* insensitive to relatively large plant parameter changes. It works well with linear and nonlinear plants. The structure applied to nonlinear plant gives the linearized approximate model described by *1/Q(s)*. Therefore it may be used for linearization. Since the structure is very robust it becomes that it may be also used to non stationary linear and nonlinear plants. Taking into account the large possible plant parameter changes, it is shown that the structure may replace some adaptive control systems. In implementations all the calculations related with approximation of the regulator "dynamics" *Q(s)* may be performed using appropriate microprocessor. Therefore the regulators implemented in appropriate microprocessors have created possibility of utilization of the proposed approach. Approximations of higher order derivatives in *Q(s)* gain noises and cause rapid and nervous change of control *u*. Therefore the proposed solution may be applied to actuators which accept these changes. Further researches concern multivariable systems.

Parallel Compensator and Its Application to Nonminimum Phase Plants

R. Gessing

Design of regulators assuring appropriate accuracy for nonminimum phase plants meets great difficulties. This is caused by the fact that usually insignificant increase of the proportional regulator gain causes instability and small gain causes law accuracy even

in a constant steady state. If the integral part is introduced in regulator, to reduce the steady state error, then its gain is also very limited giving very slow transients. In the researches, following the Smith compensator we propose for nonminimum phase plants the compensator which connected in parallel to the plant changes its model which becomes minimum phase. For the changed replacement plant model it is easy to design regulator with high gain which assures appropriate accuracy. The kind of the changed model depends upon our choice and the goal of the control. If the main goal of the control is the accuracy of stabilization under stepwise excitations then the changed model may take the form of a first order lag with the gain equal to that of the plant. The time constant of this model has also a limited influence on under- and over-shot of the step response. If the main goal of the control is tracking or disturbance rejection of signals with frequencies belonging to some working frequency band then the changed model, in the form of rational transfer function with relative order equal to one, should be chosen in this manner that it is minimum phase and in the working frequency band its frequency response is approximately the same as that of the plant. Especially in the case of stabilization the proposed system structure is very robust since the frequency response of the replacement plant model lies in the first negative quadrant of the Nyquist plain (first order lag). In the case of tracking or disturbance rejection the demand of closing the frequency response of the replacement plant to that of the plant causes some decrease of robustness, since the frequency response of the replacement plant may lay now in the first and second negative quadrants of Nyquist plain (closer to the critical point *(-1,j0)*. To the replacement plant the relay implementation of the control may be applied; it has similar properties as a continuous-time one, which results from performed simulations. It seems that the described idea of parallel compensator may be also used for other difficult plant improving accuracy at least in steady state and also robustness of the control.

Whether Delta Operator Models are Really Better for Small Sampling Periods

R. Gessing

It is known that in the case of small sampling period a large word length (WL) is needed for recording the shift operator (SO) model coefficients. Therefore the large WL is also needed for calculation of the frequency and time responses when the SO model is used. Somewhat different situation is in the case of the delta operator (DO) models which need for recording their coefficients a significantly smaller WL. The same remark concerns the analytical calculations of the frequency and time responses. However for calculations of the latter this statement is true only for such inputs which are described by some mathematical functions and for which there exists an analytical solution of the corresponding difference equation. This is a rather seldom case in applications. The superiority of the DO models over SO ones disappears in the simulation in which for any input the time response of the output is calculated. This is an important observation because in simulations usually this case appears. The same case appears in digital control implementation in which the output of the digital controller must be calculated for any current input. The superiority of the DO models over SO ones, for small sampling periods, disappears also in the case of model identification under limited measurement accuracy and relatively accurate calculations (information processing). This case is fully justified from practical point of view. The statement about the lack of the superiority of DO models is in contradiction with the common view. However this

view results from different assumption that the errors result mainly from less accurate information processing (to short mantissa used in calculations). To summarize, since the simulation for any input signal and identification under a limited measurement accuracy are (from application point of view) more important, then the statement about the superiority of the DO over SO models, for small sampling periods, seems to be not fully justified.

Two-Level Control of Large-Scale Systems with Incomplete Information

R. Gessing, Z. Duda

Control tasks in large scale systems composed of distributed subsystems are usually solved in a two-level or multi-level hierarchical structure. Very important issues in control of such systems are information and computation. Especially complicated are control problems with decentralized incomplete measurement information available for particular decision- makers. The problems related to limited resources allocation are formulated and solved. It is assumed that local controllers have detailed information essential for particular subsystems, which is aggregated and transmitted to a coordinator. Then, the amount of information transmitted to and processed by the coordinator can be significantly decreased. For coordination an elastic constraint is proposed. It leaves some freedom in taking decision by local controllers, which receiving only some directions from the coordinator can use its own information better. Owing to the elastic constraint and assumed information structure it is possible to partially decompose the calculation and to realize the decentralized control.

Another approach (without the elastic constraint) is used for a system composed of interconnected linear static subsystems. It is shown that control strategies using the elastic constraint are suboptimal. Optimal strategies are found and compared with suboptimal ones.

Robust Control Design of Nonlinear Time-Varying Systems

R. Czyba, M. Błachuta

The specific interest is application of the Dynamic Contraction Method (DCM) to the synthesis of a control system for a non-linear object. It is applied to a realistic non-linear aircraft model F-16. Dynamic properties of an aircraft depend on both its structure and aerodynamic qualities as well as on the control law applied. Classical control methods assume that the object dynamics are linear and stationary around equilibrium. Unfortunately, due to high non-linearities that occur in plant dynamics such control systems do not function correctly in extreme conditions. Therefore control of complex objects under changeable conditions needs a special approach to the subject. A way of the algorithmic solution of this problem is the application of the Localization Method (LM). The peculiarity of the LM method is the application of the higher order derivatives jointly with high gain in the control law. The generalization and development of LM is the Dynamic Contraction Method (DCM) which allows to create the desired output dynamics for non-linear and non-stationary objects assuming that information about the system parameters and the external disturbances is incomplete. In general, the goal of the design of an aircraft control system is to provide decoupling, i.e.

each output should be independently controlled by a single input, and to provide desired output transients under assumption of incomplete information about varying parameters of the aircraft model and unknown external disturbances.

Although the Dynamic Contraction Method has been applied to an aircraft model, this control method can be successfully applied in other objects, e.g. in automobile industry to design active car suspension system.

Control Systems Benchmarking and Assesment

M. Błachuta, G. Bialic

Complex systems are comprised of numerous loops which are controlled by local SISO controllers. The decision to retune or replace any of these controllers should be preceded by an investigation whether and to what extent this would improve performance. Such procedure is referred to as benchmarking or control performance assessment. Most related pieces of research done so far assume MV control as the performance lower bound.

The main point stressed in the literature is that the system delay d is known to the process engineer which seems to be too optimistic.

Another disadvantage of MV based benchmark is that it does not take the control effort into account see fig.1–2. In order to remove this drawback a modified MV strategy is considered in this paper resulting in the LQG problem.

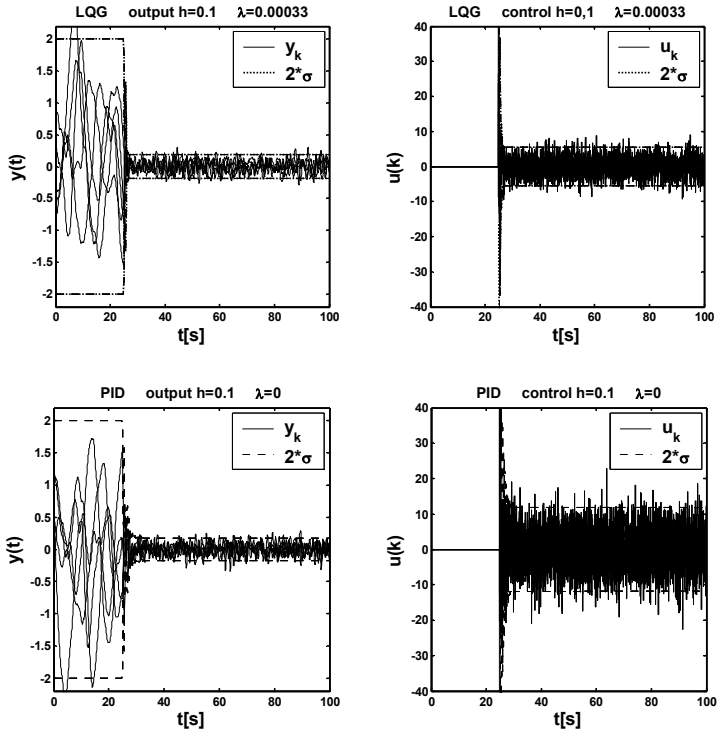


Fig. 1. Realizations of y(t) and u(t) for LQG and PID controllers with the same control quality (a → a').

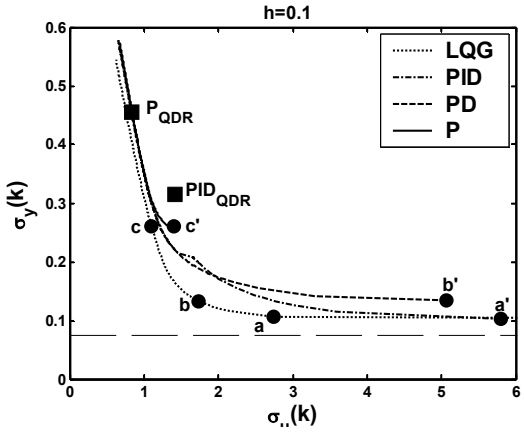


Fig. 2. Standard deviation of output vs control.

Since most of control loops in industry are equipped with PID type controllers, it is interesting to know the distance of their control performance from the best achievable one. Furthermore, it is interesting to know how the controller settings determined on the basis of the disturbance characteristics would improve the performance.

The research in this area is directed on development of performance assesment methods alternative to MV benchmark, and on optimal re-tuning of industrial controllers, accounting for disturbance characteristics.

Investigation of Properties of LQG and Predictive Controllers

M. Błachuta, R. Grygiel

The theory of predictive control is widely recognized as a design tool for modern control algorithms. Although the state-space design of predictive control has quite a large literature, there have been still some weak points, particularly when a stochastic disturbance is present in the system. In the ongoing project, these points have been clarified to a great extent. New state-space predictive control laws have been derived that are computationally more efficient and provide better quality than the classical ones.

Realistic stationary noise models have been incorporated into the design of predictive controllers within a unified framework basing on receding-horizon LQG instead of the hitherto used nonstationary models. Set-point following has been reformulated as a reference model tracing. An alternative approach to digital control of continuous-time system is being developed that bases on both the continuous-time model of the system to be controlled and a continuous-time reference model of the sampled-data system. The proposed method does not exhibit the disadvantages of prevailing purely discrete-time approach.

Appropriate reference models and their influence on control signal are chosen as the main design tools, and the results of model-system mismatch are studied extensively for both delayed and delay free systems.

Design and Analysis of 2DOF Systems with Fast Control Loops

M. Błachuta

Control systems usualy have two different tasks: reference tracking and disturbance attenuation. In standard 1DOF control systems the controller is responsible for both of them, and very often neither of them is maintained properly. Typically, controller settings are chosen so as to arrive at accectable transients after step-wise change of the set-point value, and disturbance characteristics are usually completely ignored. On the other hand, the controller settings can bo chosen to minimize the variance of the output signal but then the transients caused by set-point change can be completely unsatisfactory. The cure is a 2DOF feedback & feed-forward system where feed-forward is responsible for reference tracking, while feedback is aimed at attenuation of disturbances and minimalization of the effects of model-system mismatch. The control loop can then be designed in accordance to its own task leading to improved performance of the entire control system. Although such structure results both from our approach to LQG systems, and from Dynamic Contraction Method, the research based on higher order controllers designed in accordance with plant dynamics is rather heuristic.

Robust Digital Control of Uncertain Nonlinear Time-Varying Systems

M. Błachuta, R. Czyba

A tracking problem for output variables with the specified desired decoupled output transients under assumption of incomplete information about varying parameters of the system and external disturbances is addressed. Adaptive control methods, control systems with sliding mode, Localization Method (LM) and Dynamic Contraction Method (DCM) may be used to solve this problem in both the continuous-time and sampled-data setting. Digital controllers design methods are usually related to the purely discrete-time systems. In the case of continuous-time plants the first step to be done when using the above methods is the plant discretization, which is a great disadvantage, particularly for non-linear plants. A completely different approach is presented that bases on a pseudo-continuous-time model of the control loop with a pure time delay, for which a linear continuous-time controller is designed and then discretized by using the Tustin transformation. When the sampling rate increases, the control signal converges to the continuous-time one contributing to the improvement of the system performance. An aircraft, an industrial robot and an AC induction motor drive serve as challenging application examples for methods being developed.

Jump linear systems

A. Czornik, A. Świerniak

Modern control systems must meet performance requirements and maintain acceptable behaviour even in the presence of abrupt changes in their dynamics due, for example, to random abrupt environmental disturbances, changes in subsystems interconnections, random failures, abrupt changes in the operating point of a non-linear plant etc. This can

be found, for instance, in control of solar thermal receivers, robotic manipulator systems, aircraft control systems, large flexible structures for space stations (such as antenna, solar arrays), etc. In some cases the relevant stochastic model may consist of a set of linear systems with modal transition given by a Markov process. Such systems are called in the literature jump linear systems. For such systems problems of stability, stabilizability, controllability, detectability and observability are being considered for both continuous and discrete time cases. Different concepts of controllabilty have been already introduced but sometimes they are not suitable to practical applications [I.1], [I.5]. Therefore new concepts of controllability which seem to be more appropriate for applications are introduced [I.1]. For these definition of controllability necessary and sufficient conditions are being found and relationships with other types of controllability are under consideration. Also connections between controllability and stabilizability is investigated. Moreover appropriate LQ and LQG problems and their adaptive versions are being considered [I.39-I.42]. The applications of jump linear systems to robust and fault tolerant control is discussed [I.1], [I.5].

Identification of ingot-mould thermal resistance in continuous casting of metals

A. Nawrat

One of the most important technological parameter which influences the process of solidification of the metal in stationary or continuous casting technologies is thermal resistance of the gap between the mould and ingot. It is developed the inverse technique for identification of thermal resistance on the base of temperature measurements within the wall of the mould in the process of continuous casting of metals. Analysed problem belongs to the group of inverse problems. A research shows the possibility of applying the least squares adjustment method with *a priori data* for solving inverse problem of identification of unknown thermal resistance of gap in the process of continuous casting. The identification is based on the mathematical model of the process and on the results of temperature measurements within the wall of the mould. To apply the method the mathematical model of the process has been evaluated. The finite element method has been used for evaluation of the mathematical model of steady-state temperature field and interphase location in the analysed process of continuous casting of metals. In the researches is also considered the problem of appropriate location of the sensors for identification of ingot mould thermal resistance during continuous casting of metals is the subject of the paper. Location of the sensors is based on the results of sensitivity analysis for the steady-state inverse heat conduction problem. Validation of the proposed inverse method is realized by comparison results taken from solution of inverse and direct problems.

Translation of Block World Planning in the Presence of Uncertainty to Linear Programming

A. Gałuszka, A. Świerniak

STRIPS language is a convenient representation for artificial intelligence planning problems. There are many different algorithms of state space searching which use STRIPS representation for planning. Some of them search for a solution through a space of world-states. Because of a size of this state space it is difficult to generate an optimal plan for planning instances. Moreover in real world applications knowledge about environment is incomplete, uncertain and approximate. That is why planning in the presence of uncertainty is more complex than classical planning. To increase computational efficiency of planning with uncertainty a transformation to Linear Programming problem is proposed. Translation to Linear Programming allows reducing computational complexity of searching for the solution. That is because planning in the presence of incompleteness is usual at least NP-complete problem, Linear Programming is polynomial-time complete problem and translation from STRIPS to Linear Programming is also polynomial. The cost of this approach is that algorithm can results in non-interpretable solutions for some initial states (what is followed by assumption $N \neq NP$). Simulations that illustrate the reduced problem are implemented in MATLAB.
Keywords: planning with uncertainty, STRIPS language, linear programming.

Identification and optimization of nonlinear systems using structural sensitivity analysis.

K. Fujarewicz

A problem of optimization of nonlinear systems can be formulated in two different ways. Firstly, as a task of finding optimal control signal, secondly as a problem of searching optimal control law. When mathematical model of the system is unknown in addition a problem of identification (evaluation) of nonlinear model has to be solved at first. These three different problems can be formulated and solved using an unified structural sensitivity approach called Generalized Back Propagation Through Time (GBPTT) published by us in past years. This methodology is fully structural and mnemonic. The system should be given as a block diagram. Then, a set of simply rules is applied in order to obtain a sensitivity model and its "transposed in time" form. The last form is used to generate searched gradient of performance index in space of optimized parameters and/or signals. Because GBPTT is fully mnemonic, it was possible to create an unique software, AIDENT toolbox for Matlab, described in [I.143]. The user models of the system in Matlab Simulink specifies the performance index and optimized parameters and/or signals and finally runs optimization procedure. The AIDENT toolbox can be freely download from our web page http://software.zis.ia.polsl.gliwice.pl/aident/.

Recently, we have extended the GBPTT method to hybrid, continuous-discrete systems. The method has been used to formulate an algorithm of learning of continuous-time neural networks based on discrete-time measurements [I.11]. The same approach has been used in optimization of discrete control systems with a fractional order hold (FROH) in various structures [I.12], [I.146], [I.147].

IMAGE PROCESSING AND PATTERN RECOGNITION

Image processing and pattern recognition is one of the main research fields of the Image Processing Group. Over the years, a lot of research efforts have been focused on the application of the algorithms developed by the researchers of the Group in different areas of medicine, biology, engineering and cultural heritage preservation.
Currently our research topics include among others:

- digital image denoising and segmentation, (infrared, ultrasound, SAR, microscopy, multichannel images and video),
- processing of the microarray images acquired at the Centre of Oncology in Gliwice,
- demosaicing of CFA arrays,
- human face and eye tracking,
- establishing correspondence in stereo pairs,
- detection of microcalcifications in digital mammography,
- assessment of the quality of wavelet based compression methods,
- enhancement of MRI images,
- digital heritage preservation.

Our main interests at the moment is the human-computer interaction, based on the tracking of eyes, gestures and body movements, developing algorithms for mobile, autonomous robots and processing of historical documents and virtual restoration of historical and museum objects.

We are in close, working relations with UNESCO (Memory of the World Project), different research centers in Italy, Germany, Norway, USA and Canada, (our main partner is the University of Toronto, Image Processing Lab headed by Prof. A.N. Venetsanopoulos). We are open for cooperation in interesting research and application projects, in which we could bring our experience gained during the work on the above mentioned research topics.

Enhancement and Analysis of the Biomedical Images

B. Smołka, A. Świerniak

Image processing and quantitative analysis of electrophoresis images play an important role in the modern biomedical diagnostics. As the images are most commonly very noisy and of nonhomogeneous illumination, new techniques of noise reduction and contrast enhancement have been developed. The new methods outperforms the standard techniques of image enhancement and can be applied to both gray scale and color images in many medical and also industrial applications. The basic idea behind the new methods of noise reduction and contrast enhancement is the introduction of the random walk concepts into the image processing. Our special interest is devoted to the analysis of single cell gel electrophoresis (SCGE). A novel method of segmentation of those images has been developed and applied for the evaluation of the DNA damages of patients treated with radiotherapy]. Additionally new parameters describing the level of the DNA strands breakage has been proposed and applied to the evaluation of the SCGE images.

The quantitative evaluation of microarray images is a difficult task. The major sources of uncertainty in spot finding and measuring the gene expression are variable

spot sizes and positions, variation of the image background and various image artifacts. Spots vary significantly in size and position within their vignettes despite the use of precise robotic tools to lay them out onto the slide. Additionally the natural fluorescence of the glass slide and non-specifically bounded DNA or dye molecules add a substantial noise floor to the microarray image. To make the task even more challenging, the microarrays are also afflicted with discrete image artifacts such as highly fluorescent dust particles, unattached dye, salt deposits from evaporated solvents, fibers and various airborne debris. The research led to developing a novel method of noise reduction in micraarray images. The new technique is capable of attenuating both impulsive and Gaussian noise, while preserving and even enhancing sharpness of the image edges. Extensive simulations reveal that the new method outperforms significantly the standard techniques widely used in multivariate signal processing. In our method we apply new noise reduction methods for the enhancement of the images of gene chips. It was demonstrated that the new techniques are capable of reducing impulsive noise present in microarray images and that they enable efficient spot location and estimation of the gene expression level due to the smoothing effect and preservation of the spot edges.

Colour and hyperspectral images contour detection

A. Polański, R. Bieda

Edge detection is a very important process in vision systems to use for image understanding and scene analysis by either computer-based systems or men. Determination of object boundaries is important in many areas such as medical imaging (X-ray image analysis, computer tomography, mammography), dactyloscopy, quality control, photogrammetry (analysis of satellite and aerial pictures) and intelligent robotic systems (visual systems for object recognition and classification).

Edges in grey-level images can by thought of as pixel locations of abrupt grey-level change. A change in the image function can be described by a gradient that point in the direction of the largest growth of the image function.

Our research concentrates on the following low-level *m*-channels image processing problems based on edge and contour objects detection.

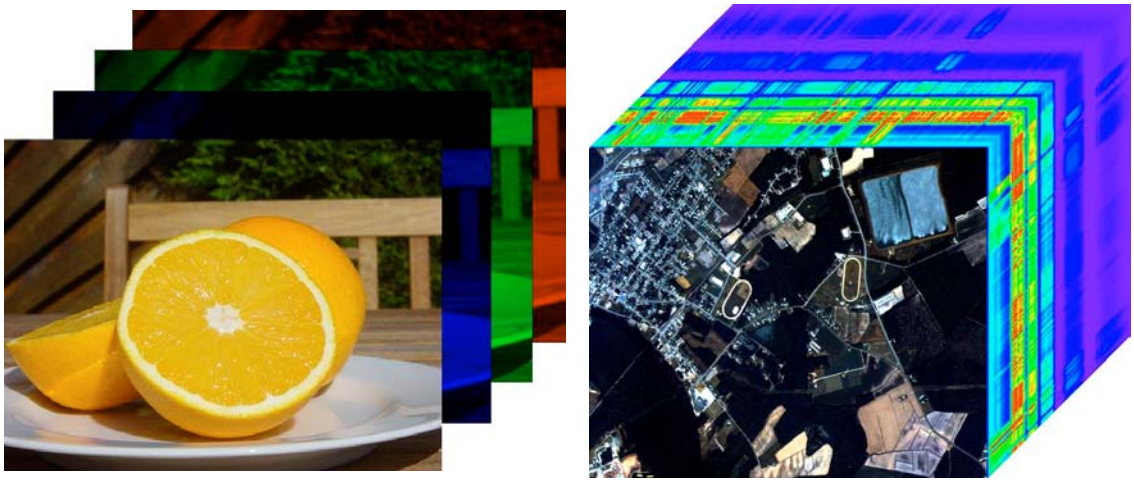


Fig. 1. Example of colour images witch three channels and hyperspectral cube image with 224 –channels.

While edge detection in grey-level images is a well-established area, edge detection in colour (e.g. in RGB space m=3) and hyperspectral (e.g. in AVIRIS data m=224) images has not received the same attention. The fundamental difference between colour/hyperspectral images and grey-level images is that, in a colour/hyperspectral image, a m-components vector is assigned to a pixel, while a scalar grey-level is assigned is a pixel of a grey level image.

The aim of the methods of image contour detection is the information which will be used in segmentation process or object recognition. Current research is focused on tested method based on kernel end spectral-pattern edge detection.

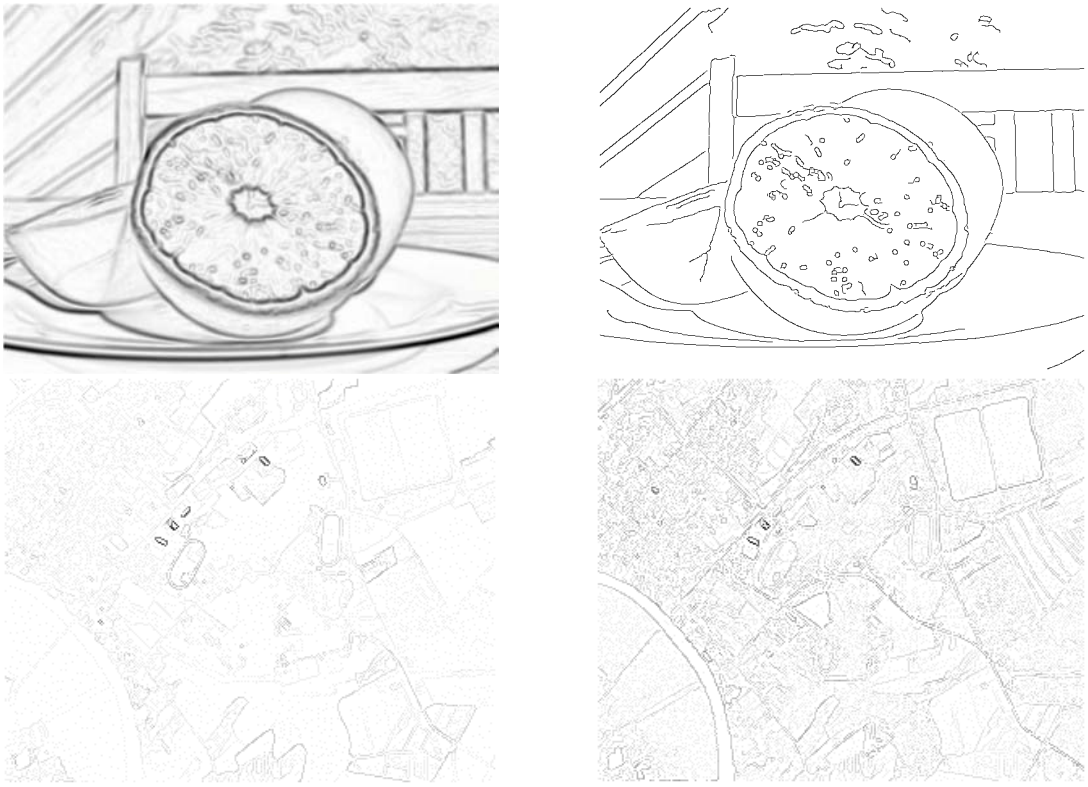


Fig. 2. Example of gradient map and contour of colour image (top row), and gradient map of hyperspectral images for 190-channel with Triangular kernel and 55-channel for Gaussian kernel (bottom row).

BIOMATHEMATICAL RESEARCH

Members of the Control Theory Group are co-organizers of the first high-density DNA microarrays laboratory in Central-Eastern Europe located in the Institute of Oncology, branch Gliwice, Department of Endocrinology and Nuclear Medicine, and are principal investigators of research projects developed there.

DNA microarray technology promises a breakthrough in studies on pathogenesis and therapy of cancer, since it enables assessing changes in the expression level of numerous genes, allowing not only a better understanding of neoplastic transformation and progression, but also a more accurate classification of cancer subtypes, pre-diction of the optimal therapy and prognosis of outcome. Wealth of data gained by microarray studies require closer interdisciplinary cooperation than it has been practiced until now.

The aim of the project is to perform a number of specific tumour gene expression profiling studies directed to the area of interest of participating groups, to analyse them by optimised mathematical modelling and next to make them open for further cross-comparisons in order to improve our understanding of tumour biology and answering clinical questions.

Control and Estimation in Cell Populations

M. Kimmel, A. Świerniak, Z. Duda, A. Polański, J. Polańska, J. Śmieja

Two major obstacles against successful chemotherapy of cancer are (1) the cell-cycle-phase dependence of treatment, and (2) the emergence of resistance of cancer cells to cytotoxic agents. One way to understand and overcome these problems is to apply optimal control theory to mathematical models of cell cycle dynamics. In the elaborated models the control actions represent drug dosage or, more generally, therapeutic protocols and a region of the disease parameters considered as admissible defines a target set for the state. In the case of cancers the disease state should be represented by the size of the tumor defined for example by the number of transformed cells. Unfortunately any control action i.e. treatment by drugs does not selectively disturb cancer tissues. Both chemotherapeutic agents or radiation act on normal tissues. Thus, the control problem becomes much more intricate than in many industrial applications, the more that the unperturbed system (i.e. when therapy is not applied) leads always to undesirable outcome. The study of these models leads not only to new results in optimisation and estimation theory as well as in their applications in oncological practice.

Another important aspect in this field that has been addressed is the problem of prediction of treatment results.

Branching random walk models in cell biology

M. Kimmel, Świerniak, A. Polański, J. Śmieja

The purpose of this research is to build and analyze models of population dynamics on the molecular level basing on techniques originated from theory of stochastic processes. The mathematical models of three different molecular phenomena i.e. evolution of DNA repeats uncontrollable changes of which accompany some genetic diseases, gene amplification in cancer cells conferring resistance to chemotherapeutic drugs and telomere shortening supposed to be mechanism of aging and death, indicate two mechanism of stochastic nature which should be taken into account: (1) stochastic changes in number of copies from one generation to another and (2) the stochastic variablity in cell lifetimes. The stochastic process which accommodates both (1) and (2) is a random walk superimposed in the time-continuous branching process i.e., a branching random walk. Methods of analysis of the model constructed on this basis include Laplace transforms, asymptotic expansion of integrals and special functions, spectral analysis and semigroup theory, and enable study of asymptotic behaviour of the considered molecular phenomena.

Modeling of Tumor Cell Antidrug Resistance

A. Swierniak, J. Śmieja

In this research the models based on amplification of the resistance gene up to a very large number of copies are considered. The approach is to study basic mathematical properties of the models, in hope they will be of help in understanding the control problem. It is interesting that in molecular biology we are frequently dealing with very long and highly variable repeated structures like amplified genes arrays, DNA triplet repeats or telomere endings. If this is the mechanism of drug resistance, then finite-dimensional models will fail. They cannot account for the depth of the "tails" of the distributions of force of resistance (it is known that a lot of copies of the gene can be passed). Results of this research may be used to show desired form of optimal treatment protocol and give certain hints to its development. They can be also utilised in qualitative analysis of chosen protocol, taking into account both increasing resistance to the chemoterapeutic agents and allowing multidrug and phase-specific treatments. It is believed that the infinite-dimensional formulation is more useful and simpler than its finite-dimensional truncations. If the resistance does not have to do with repeated structures, then the multiple new variants of resistant cells may arise by point mutations, in accordance with e.g. the infinite alleles model.

Supervised and unsupervised analysis of gene expression data

K. Fujarewicz, K. Simek, M.Kimmel, A. Świerniak

Recent development of experimental techniques like cDNA microarrays and oligonucleotide chips attracted a lot of research interest. The novel methods permit to measure expression levels of thousands of genes in a massively parallel way. Their main advantages are reproducibility and scalability of obtained data and short time of one experiment. The new data resulting from the experiments promise to enhance fundamental understanding of life on the molecular level, from regulation of gene expression and gene function to cellular mechanisms, and may prove useful in medical diagnosis, treatment and drug design. Analysis of these data requires mathematical tools that are adaptable to the large quantities of data, while reducing the complexity of the data to make them comprehensible.

So far gene expression data have been used successfully to classify the cancer type of a given sample or classify groups of co-regulated genes. Our research follows the mainstream of the analysis. We have tested several, new and existing, methods of classification , and showed that a selection of proper (optimal) set of genes, which expression can be used for classification, is still an open problem. A new method of selecting differentially expressed genes, Recurrent Feature Replacement (RFR), based on support vector machines technique, has been proposed in [I.52]. It has been tested [I.53], [I.142] on different data sets and compared to other selection methods, recently proposed in literature. The best results have been obtained when the RFR method has been combined with Recurrent Feature Elimination (RFE) method [I.144]. In works [I.81], [I.213] we proposed permutation tests as a method of validation of obtained classifier.

Recently, data on multiple gene expression at sequential time points were analyzed, using Singular Value Decomposition (SVD) as a means to capture dominant

trends, called characteristic modes, followed by fitting of a linear discrete-time dynamical system in which the expression values at a given time point are linear combinations of the values at a previous time point. We attempt to address several aspects of the approach [I.81], [I.175]. To obtain the model we formulate a nonlinear optimization problem and present efficient way to solve it numerically. We use publicly available data to test the approach. We discuss the possible consequences of data regularization, called sometimes ``polishing", on the outcome of analysis, especially when model is to be used for prediction purposes. Then, we investigate the sensitivity of the method to missing measurements and its possibilities to reconstruct missing data. The results point out that approximation of multiple gene expression data preceded by SVD provides some insight into its dynamics but may also lead to unexpected difficulties, like overfitting problems.

All supervised and unsupervised method of analysis, mentioned above, have been used in our collaborative works [I.110-I.113], [I.211], [I.213], [I.220], [I.227].

Gaussian mixture approach to the analysis of microarray data

J.Polańska, A.Polański

DNA microarray expression profiles analysis can require performing quite complicated processing. Despite using models and mathematics, a lot of heuristics and intuition is necessary to interpret data. It involves choosing between algorithms and between values of numerous parameters. It seems that best achievements are obtained by using combinations of described approaches. When deciding about order of operations and parameter values to be applied, statistical analysis of samples is most valuable. An important aspect for microarray data analysis is the possibility of experiment repetition, or similarly possibility of collecting multiple samples characteristic to some experimental conditions or situation. Some issues can be very efficiently resolved when experiments are repeated many times, but become very difficult otherwise. Modeling distribution of pdfs by Gaussian mixtures allows studying cluster properties following from similar values of logarithms of gene expressions by setting thresholds to classify expression levels as "change", "no change", "overexpressed", "underexpressed" etc., based on pdfs of estimated components. Mixture model analysis can be enhanced by incorporating information on measurement repeticion into construction of likelihood function. It is natural to accept the assumption that all measurements of expressions of one gene belong to the same component of the mixture distribution. The assumption on gluing together measurements for one gene can easily be incorporated in construction of the likelihood function.

Inferring cause – effect relations from gene expression profiles

A.Polański, J.Polańska

Comparisons of gene expression profiles in cancer and normal cells lead to publishing lists of cancer–versus–normal differentially expressed genes, often ordered with respect to their differentiating power determined by several approaches, e.g., by the p-value of a statistical test. Cancer arises as a result of accumulated

genetic alterations, many of which result in altered gene expression. Tumors appear to select for genetic abnormalities that may be most advantageous for escape from normal regulatory mechanisms in their particular microenvironment. However, for most genes their altered expression is rather a consequence than a cause of neoplastic transformation and many of the observed changes are irrelevant for tumor biology. Thus, when contemplating comparisons of cancer–versus–normal expression profiles, a question arises on causality of relations implied by the detected differences in gene expressions. If gene X is expressed differentially in cancer versus normal cells, then is it a cause or rather an effect of the ongoing neoplastic transformation? Computational approach uses models of Bayesian Networks. Since the causes and effects of neoplasia are not directly related to networks of gene interactions themselves, but rather follow from their deregulation, the declarative Bayesian Networks approach is proposed. It reflects how one could reasonably imagine the random mechanism of triggering neoplastic processes by altered gene expressions. These networks correlate very well with real data and allow to infer genes roles, causes or effects, by maximizing likelihood functions of the constructed networks.

Modeling and parameter estimation of cell signaling pathways

K. Fujarewicz, M. Kimmel, A. Świerniak

Mathematical models of cell signaling pathways frequently take form of sets of nonlinear ordinary differential equations. To compare different models and to test their ability to model processes, for which experimental data are available, an efficient method of parameter fitting is needed. Unfortunately, while the model is continuous in time, all available measurement techniques, such as: Western blot expression analysis, electrophoretic mobility shift assays or gene expression microarrays, provide measurements at discrete time moments only. Moreover, these time moments may be non-uniformly distributed and may be different for different signals measured. Hence the problem of estimation of model parameters has dual nature: the model is continuous-timed but the performance index is discrete, sum-quadratic.

Generalized Backpropagation Through Time (GBPTT) method, developed by us in the past and recently extended to continuous-discrete systems [I.106] is a tool which can be applied to solve the problem stated above. In [I.49], [I.104] GBPTT has been successfully applied in the case when measurements were the output of known model taken at discrete-time moments.

Unfortunately, in practice the data are produced by blotting techniques. These methods produce images and the information about concentrations of particular substrates are only semi-quantitative. In most cases concentration levels may be compared within one blot and cannot be compared to concentrations estimated based on other blots. This is the second difficulty appearing in practice. To solve it we assumed existence of unknown multipliers (one multiplier per one blot) and estimate them using the same GBPTT methodology. The proposed approach has been applied [I.49], [I.145] to estimate the parameters of the model of NFkappaB transcription factor, recently proposed in literature.

Model of evolution at a pair of SNP loci under mutation, genetic drift and recombination

M.Kimmel, J.Polańska

Linkage Disequilibrium (LD) has been one of the most intensely studied subjects in population genetics. Introduction of Single Nucleotide Polymorphisms (SNPs) and sequencing of the human genome seem to be the turning points for these studies. Ubiquity of SNPs and the possibility of anchoring them in the human genome sequence contribute in this trend. Why are we interested in LD? Pragmatic reasons include identification of regions with markers appropriate for disease-association studies. However, there also exist basic questions regarding evolution of the modern human genome which may be elucidated by studying LD. One of these questions is the influence of past demographic trends on current LD. Another question is the age of SNPs. Still another is the relative importance of the basic genetic forces for evolution of LD. Genetic forces responsible for the observed pattern of LD are recombination, genetic drift, mutation and selection. Even if selective neutrality is assumed, joint consideration of the remaining three forces is quite complicated and is usually considered to require simulation methods. These usually are based on the coalescence process and are powerful but computationally intensive. To answer these questions a model of evolution at a pair of SNP loci, under mutation, genetic drift and recombination is proposed where mutation is modeled using a two-state Markov model. The model is extremely fast computationally, which makes possible to review a large number of parameter values and different demographic scenarios in a short time. We obtain estimates of the age of population expansion of modern humans, which are consistent with the consensus estimates. In addition, we are able to estimate the ages of the polymorphisms observed in different genomic regions and we find that they vary widely with respect to their age.

Statistical evaluation of familial risk factors in type 1 diabetes mellitus

J.Polańska

Type 1 diabetes is a juvenile immune system disease that leads to destruction of pancreatic cells and, eventually, to the loss of the ability of insulin production. In many countries (among them Poland) the incidence of type 1 diabetes has been substantially increasing in recent years. Increasing incidence and unknown aetiology of the disease motivates epidemiological studies of possible risk factors (autoimmunological, genetic or environmental). It is believed that the immunopathogenic process may be triggered by several environmental factors such as viral infections, stress or chemical substances from the air or water. It also seems that susceptibility of a child to the disease can be associated to perinatal factors, e.g. birth weight or parental age at the moment of the child's birth. It is well known that maternal age over 35 years of age results in increased susceptibility of the child to several diseases. So it seems possible that increasing incidence of type 1 diabetes can be at least partly related to the tendency of late motherhood observed more frequently in industrialized countries. However, in order to be precise in statements regarding the growing incidence of type 1 diabetes to increased maternal age at the moment of giving birth to their children, a statistical study must be performed to answer the following questions: (i) are children born from mothers over 35 years of age exposed to increased risk of being affected by type 1 diabetes?, (ii) how

does this risk depend on mother's age at the moment of child's birth? Statistical research on familiar risks for type 1 diabetes must be rather carefully designed, due to the existence of the mechanism of bias in estimating levels of risk resulting from different susceptibilities to risk to type 1 diabetes of children born in different birth order in the family. In order to avoid bias, maternal age must be analyzed in parallel with other risk factors, specifically with the child's birth order. Several approaches could be applied for estimating risks: contingency tables and odds ratios, logistic regression and, most general, non - parametric models with moment estimators for coefficients.

The EM algorithm and its implementation for the estimation of frequencies of SNP-haplotypes

J.Polańska, M.Kimmel

Much of recent research in clinical genetics relies on resolving genetic structure of complex diseases (traits). Complex genetic traits are linked with DNA loci located in multiple regions in the genome. Eventually, the studies will allow associating risks for complex diseases with sets of specified haplotypes. Problems to be solved to achieve this aim stem from (1) necessity to carry out large population-based studies and to collect large amount of data, and (2) necessity to develop robust and efficient numerical algorithms for haplotype reconstruction from unphased genotypes. The first practical approach to solve the problem of haplotype reconstruction from unphased genotype data was a parsimony - type method. Necessity to better use the information contained in the collected samples led to the increased interest in maximum likelihood estimates of haplotype structure. However, the likelihood function associated with samples of unphased genotypes with underlying haplotype structure is complicated and cannot be maximized by standard techniques. A breakthrough was the application of the Expectation Maximization (EM) method to maximize the likelihood of observed genotype data. Due to the interest in haplotype blocks, coming from the abundance of SNP data, the problem of accuracy and reliability of haplotype reconstruction methods significantly gained importance. Despite many studies on the properties of the EM algorithm, several problems related to its application are still unsolved. Among the most important are: determining the speed of convergence, sensitivity to the stopping criterion and existence of multiple local maxima. We have developed a Matlab - based implementation of the EM method. Using our program we study and illustrate several aspects of the EM application: speed of convergence, reliability of estimates, and existence of multiple solutions.

Computational methods for docking ligands to protein active sites

A. Polanski, Z. Starosolski, M. Pacholczyk, A. Owczarek, P. Wolanczyk, M. Kimmel

The aim of this study is identification of parameters of models for computing interaction binding affinities (energies) between certain chemical molecules. The work plan has the following elements: (1) Overview the static models for computing energies of ligand-ligand and protein-ligand interactions. (2) Download, from available databases, data describing relative positions and conformations of ligands and proteins. (3) Estimate

parameters of models using suitable optimization methods and hypotheses.

One of the models with which we already have experience is SCORE 1

$$\Delta G_{binding} = \Delta G_0 + \Delta G_{hb} \sum_{h-bonds} f(\Delta R, \Delta\alpha) + \Delta G_{ionic} \sum_{ionic} f(\Delta R, \Delta\alpha) + \Delta G_{lipo} \left| A_{lipo} \right| + \Delta G_{rot} NROT$$

In the above $\Delta G_{binding}$ – free energy of the binding, ΔG_0 – constant binding energy connected with loss of rotational and translational entropy of the ligand, ΔG_{hb}, ΔG_{ionic} contributions from the ideal hydrogen bond and the ideal ionic bond, ΔG_{lipo}- contribution from lipophilic interaction, $|A_{lipo}|$- lipophilic contact surface, ΔG_{rot} – reduction of binding energy connected with loss of degree of freedom in the ligand, *NROT* – the number of acyclic rotatable bonds in ligand, $f(\Delta R, \Delta\alpha)$ – penalty function, accounting for deviations ΔR from the ideal length and the ideal angle $\Delta\alpha$ of a hydrogen bond.

Protein databanks include already around 30,000 protein structures, many of them complexed with ligands. In our study, we will use a carefully defined subset of these structures to estimate constants present in energy function such as the one presented above. The idea is to find constants, which result in docking solutions as close as possible to those listed in the databanks.

We will collaborate with chemists from the Silesian University.

GRADUATE COURSES

- Control theory (lectures, classroom exercises, laboratories), Polish, English,
- Optimization theory (lectures, classroom exercises, laboratories), Polish, English,
- Pattern recognition (lectures, classroom exercises, laboratories) Polish, English,
- Introduction to system dynamics (lecture, classroom exercises), Polish, English,
- Quality Control (lecture, laboratories), Polish, English,
- Probability theory and mathematical statistics (lectures, classroom exercises), Polish, English,
- Artificial intelligence for robots (lectures, laboratories), Polish,
- CAD of control systems (lectures, laboratories, project), Polish,
- Control and estimation in uncertain environment (lectures, laboratories), Polish,
- Control of large-scale systems (lecture, classroom exercises, laboratories), Polish,
- Object programming (lecture, laboratories), Polish,
- Internet technologies (projects), Polish.

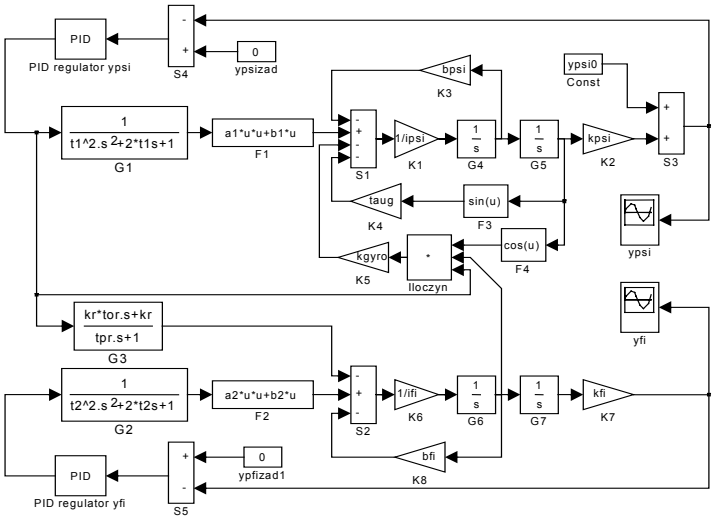
LABORATORY AND RESEARCH EQUIPMENT

Helicopter Model.

Helicopter model is a laboratory and research station manufactured by TQ International in cooperation with Humusoft. The model, with two degrees of freedom, is moved by two propellers (main and side) driven by DC engines, (photo below). Its configuration enables control by a PC computer. It is equipped with the software interface enabling real-time control from Matlab.

The plant provides a wealth of control system design and analysis features that make it very useful for education and research purposes. The mathematical model of the helicopter exhibits natural nonlinearitiy, instability and significant cross-coupling between two control channels. The range of possible experiments covers such areas as dynamical systems study, derivation of the mathematical model, linearization, simplification, identification, state feedback design, decoupling, robustness analysis and design etc.

During the experiments in the Department the system was enriched with additional software for Matlab and Simulink that enable solving some problems of controllers design and control system analysis as well as simulating closed loop or open loop systems or their elements. The figure below presents the Simulink block diagram of the helicopter model with two PID controllers driving its main and side propellers.



Simulink block diagram of the helicopter model with two PID controllers

Coupled Tank Apparatus

The Coupled Tank Apparatus is a laboratory station designed for the theoretical study and practical investigation of basic and advanced control engineering principles. It relates specifically to fluid transport and liquid level control problems as they would typically occur in process control industries. It may also, however, be used as a practical introduction to the design, operation and application of control systems in general.

The system configuration for the Coupled Tank Apparatus is shown in the figure. The Unit is shown adjacent to a CE122 Controller and an IBM compatible PC.
The station provides a safe, adaptable and self-contained facility for students of control engineering so that they may practically investigate and compare a wide range of functional control system configuration using analogue and/or digital techniques. The scope and content of performed experiments correspond with the usual development sequence used in industry. Starting with the calibration of transducers and actuators, leading to static characteristics and dynamical response testing and, finally, controller design. Full access to the sensors actuators and power supplies is provided. In this way it is also possible to make use of any other available laboratory instrumentation, such as oscilloscopes, plotters, etc.

Laboratory of Digital Archiving

One of our research topics is the digital heritage preservation. As it is obvious that historical documents are one of the most valued cultural heritages of any nation, for centuries, incunabula, maps, music sheets, manuscripts, facsimile and old prints have been carefully stored, archived and protected over times of wars and natural disasters, in order to preserve them for future generations. Unfortunately, the historical documents deteriorate with time in many ways. Vellum, canvas, paper, ink and print are exposed to aggressive chemical, physical and biological factors, which in turn leads to slow but inevitable and permanent loss of valuable exhibits.

This great danger is forcing to take prompt counter-measures in order to preserve our cultural heritage for future generations. Because of inevitable process of total natural destruction that's due to happen to many items in nearest future, the only way of preserving the collection is to save the information content and make exact copies of originals by analog or digital acquisition of document images.

We are convinced that modern techniques of digital collection, storage and display are the only durable and relatively cheap way to preserve the information value of documents and the only effective method of making public the knowledge about collections of documents: manuscripts, incunabula, books, maps and historical documents preserved in museums and libraries.

Such actions allow securing informational values of the documents and making them available to general public. It is especially important considering the fact that optimal document storage conditions, i.e. in separation from damaging external

influences, often limit the access to the documents, even making them unavailable to larger groups of specialists.

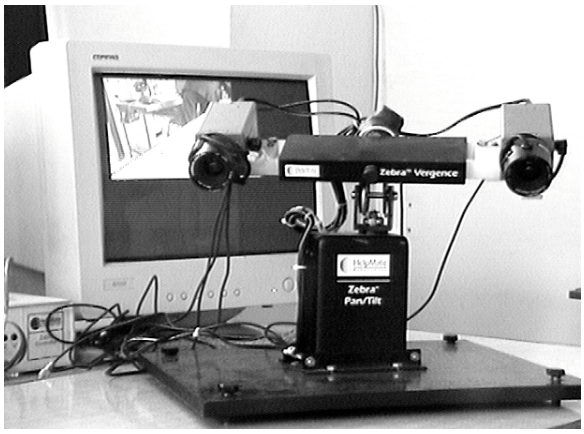
Archiving the information layer of the document indirectly prolongs its physical existence, because the need to make the original document accessible is eliminated, at least in majority of the access requests where only the information contained in the document is needed.

Our research work is focused mainly on issues of digital acquisition, image preprocessing, archiving and multimedial presentation of collections.

Laboratory equipment (main elements):

- large format (4×5) view camera Cambo Ultima Digital,
- high-performance digital scan back Better Light 4000E-HS — technical data: uninterpolated resolution 3750×5000, single-pass color or monochrome scanning, continuously adjustable color balance in 0.1 CC steps, 11 f-stop dynamic range,
- four Bowens continuous light source utilizes a specially designed fluorescent lamp to produce a cold, daylight-balanced, safety for historical objects illumination,
- Manfrotto photo and light equipment,
- Lastolite light tens and reflectors.

Active stereovision system



Active stereovision system consists of a stereo head: ZEBRA Pan/Tilt Base system and Vergence Head for servo control of azimuth, elevation and vergence angle for two cameras (manufactured by HelpMate Robotics Inc, USA).

The station is equipped with two color CCD COHU cameras with Cosmicar/Pentax auto iris lenses. The cameras are connected to PC computer by Matrox Morphis frame grabber card. The Active Stereovision laboratory setup is presented in the photography.

Magnetic levitation system

Magnetic levitation system (MLS) is a complex system manufactured by Feedback Corporation. It contains Magnetic Levitation Unit 33-210 (electromagnet, photo-sensor axis, analog controller and power adapter), analog interface, I/O pc-card and software: procedures and main control program implemented in Matlab environment. MLS contains module: Real Task Kernel which collect data in real-time. Full access to the sensors actuators is available. It has real and safe facility for students of

control theory and practice engineering.

The main purpose of MLS is to control the vertical position of iron ball in electromagnetic field. The mathematical model of phenomena magnetic levitation is based on the basics equations of physics and mechanics. The dynamic behavior of MLS is modeled by differential equations. It presents non-linearity and it is naturally unstable. It is possible to change all the parameters of mathematical model for the research purpose MLS permits different type of control algorithms to be investigated. The possible tasks approach such problems as state feedback control, mathematics model identification, linearization, simplification, etc.

Digital Pendulum System

Pendulum model is a laboratory and research station designed for theoretical study and practical investigation of non-linear system that has complex dynamic behavior and creates serious control problem. The pendulum - cart set-up consist of a pole mounted on a cart in such a way that the pole can swing only in the vertical plane. The cart is driven by a DC motor (photo below). Its configuration enables control by an IBM PC computer.

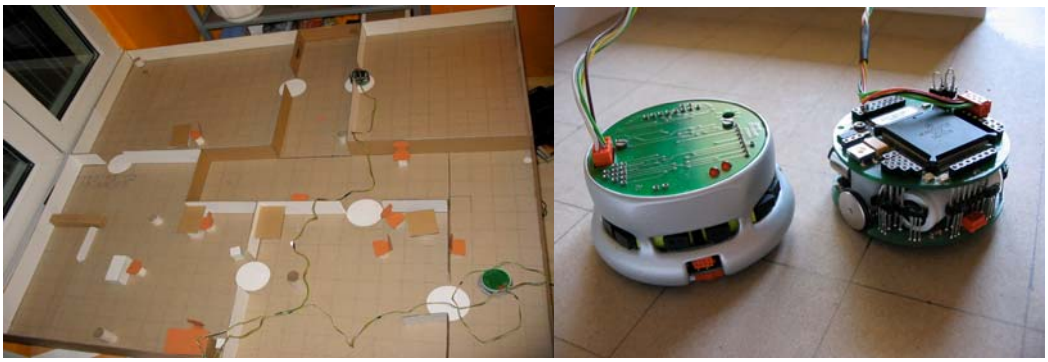
A wealth of control system design and analysis features that the plant provides, make it very useful for education and research problems. The cart - pendulum model shows the natural nonlinearity and instability that make it very difficult for control. It also provides wide range of possible investigations such as derivation of the mathematical model, linearization, simplification, identification, dynamic system analysis and design. Included external DLL library interface makes the system architecture open and allows a user to modify and change implemented control algorithms.

Laboratory Setup for Examining Mobile Robots Navigation Problems

The laboratory setup consists of two miniature laboratory, mobile robots *Khepera* and the model of a complex structured, human made workspace. The robots are controlled by the PC computer with the use of serial communication protocol RS232. The robots are miniature, differentially driven platforms equipped with infra red proximity sensors and with optical encoders associated with each of two DC motors. The robots reflects all the features of real, large dimensional mobile robots.

The setup so far, has been exploited for developing and testing algorithms for multi robot coordination based on elements of the Theory of Games. The example is the algorithm of an exploration of complex structured office like environment by the two mobile robots, that was designed and verified with the use of presented setup.

The setup provides a wealth of multi robot motion planning algorithms design and analysis features that make it very useful tool for the research purposes. All the algorithms can be easily applied in the *MATLAB* environment, what makes it also ideal for an education.



(a) (b)

The model of the office like workspace (a) and two mobile robots (b)

Mobile robot systems

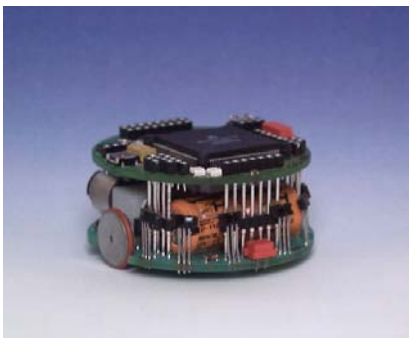
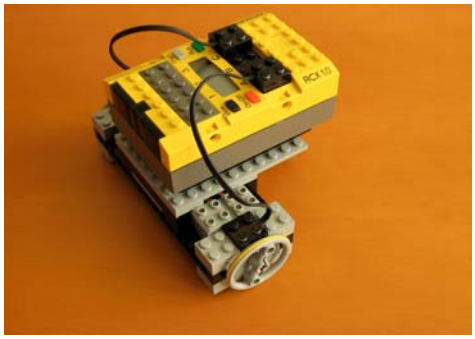
The laboratory is equipped with two *Khepera* robots, two sets of *LEGO MindStorms - Robotic Invention System*, two colour CCD cameras, ultrasound and IR sensors, six soccer robots. We also have special development tools like MPLAB ICE 2000, MPLAB ICD 2 Debugger and dsPIC Development Board.

MPLAB ICE 2000 is a full-featured emulator system providing full speed (up to 25 MHz) emulation, low voltage operation, 32K by 128-bit trace, and up to 65,535 breakpoints. It is small, portable and lightweight. Interchangeable processor modules allow the system to be easily configured to emulate different processors. Complex triggering provides sophisticated trace analysis and precision breakpoints. The trace analyzer captures real-time execution addresses, opcodes and read/writes of external data. It also traces all file register RAM usage showing internal addresses and data values, as well as all accesses to special function registers, including I/O, timers and peripherals. Triggers and breakpoints can be set on single events, multiple events and sequences of events. The MPLAB ICE 2000 analyzer is fully transparent and does not require halting the processor to view the trace.

MPLAB ICD 2 is a low cost, real-time debugger and programmer for selected PICmicro® MCUs. Using Microchip Technology's proprietary In-Circuit Debug functions, programs can be downloaded, executed in real time and examined in detail using the debug functions of MPLAB. Watch variables and breakpoints can be set from symbolic labels in C or assembly source code, and single stepping can be done through C source line, assembly code level, or from a mixed C source and generated assembly level listing. MPLAB ICD 2 can also be used as a development programmer for supported PICmicro MCUs.

The dsPIC® Digital Signal Controller (DSC) from Microchip is a powerful 16-bit (data) modified Harvard RISC machine that combines the control advantages of a high-performance 16-bit microcontroller (MCU) with the high computation speed of a fully implemented digital signal processor (DSP) to produce a tightly coupled single-chip single-instruction stream solution for embedded systems design.

The system is used for research in such areas as: trajectory planning, collision avoidance, on-line control in Cartesian coordinates, vision based control, autonomous mobile robot systems etc.

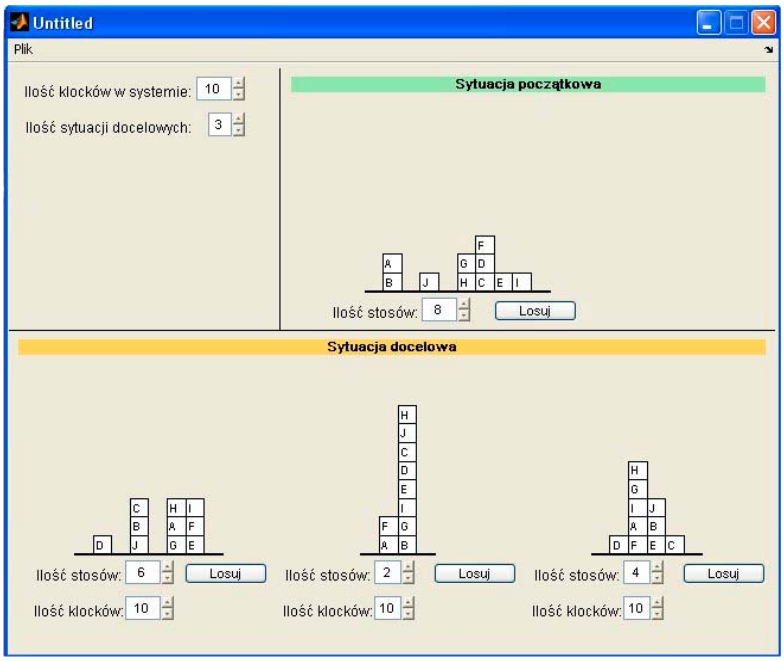
Khepera and LEGO Mindstorms robots


QTeam soccer robots and dsPIC (Microchip) development tool


Our proto board and Turtle robot equipped in wireless color camera

Block World

Within the laboratory "Artificial Intelligence in Robotics" classical problems of planning robot tasks are investigated. Part class of these problems can be represented by so called Block World environment (see figure). The environment is modelled by classical for AI methods language - STRIPS system. This environment today stated as an experimentation benchmark for planning algorithms. Also more realistic situations can be presented as Block World problems, where moving blocks corresponds to moving different objects like packages, trucks and planes. The case of Block World problem where the table has a limited capacity corresponds to a container-loading problem. The tools that deals with Block World was developed using MATLAB software and PROLOG language.



Block world environment with one initial state and disjunction of goal states.

Laboratory Setup for automatic control of UAV (Unmanned Arial Vehicle)

The laboratory setup consists of physical helicopter model Hirobo SST EAGLE2-GS Long Tail fixed on the helicopter stand which allows to perform tests in the laboratory. Helicopter is controlled manually through the RC-aperture and can be also controlled by the PC computer with the use of serial communication protocol RS232 and the wireless radio line. Helicopter hardware-software platform is equipped with Novatel GPS - OEM4-G2L-RT20W with GPS-512 antenna, laser and ultrasound altimeter, 3 gyros and 2 accelerometers build in the MEMS technology (by Analog Device Company).

On the base on the rich theoretical experience of the group and practical experience in the field of constructing electronically controlled systems of mobile robots, it is build automatic control system of the flying object (helicopter model, airplane model). For this purpose new control algorithms robust for random disturbances (abrupt and unpredictable wind blows) are designed.

Moreover the experience of the group in image processing is used to

construct active image canvassing system for the flying object, which can be applied together with the automatic control system for realization of the two following tasks. The first is on line building of three dimensional ground maps. The second one is searching objects in the urban terrain (feature of the searching object are transmitted from the ground basis to the UAV, when the UAV is already in the air (flying mission)) and following it. The information about the localization and direction of relocation of the searching object has to be transmitted to the ground basis.

Software

The group is equipped with educational licenses of basic programming tools, such as Pascal, C++ etc. However, the main research activities as well as teaching courses, are supported by the specialized programs for engineering and scientific calculations:

Matlab + toolboxes + Simulink (research and educational licenses). Matlab, elaborated by Math Works Inc., is a specialized software for engineering and scientific computation. It can be enriched with additional toolboxes (control, identification, neural networks, optimization, symbolic calculations etc.) for solving specialized problems. It can also be equipped with Simulink - a package for real - time simulation,

dSPACE – (research license) is a complete software/hardware environment for developing of real time control systems and real time simulation. It is equipped with complete experimental environment with optimal connetion to Matlab/Simulink and $Matrix_{X,}$

$MATRIX_X$ (research licence). $MATRIX_X$ is a sophisticated simulation environment that can be used to model dynamic systems. It handles continuous, discrete, linear, or nonlinear systems,

Mathematica (research license). Mathematica was elaborated by Wolfram Research Inc. It is a specialized software for scientific computation,

PSI (educational license) elaborated by Boza Automatizirung. PSI is a specialized program for simulation of nonlinear continuous and discrete systems,

CC (research and educational license) elaborated by P.M.Thompson, Systems Technology Inc.. CC is a software package for analysis and design of linear control systems,

S-plus – (research license) is a professional statistical software package suitable for acquisition and manipulation of large data sets, as well as performing all kinds of statistical tests and analyses,

Visual.NET (MSDN Academic Alliance) – is a fully development environment for building application for PC computers using C, C++ and C# languages. Visual.NET is a product of Microsoft,

MPLAB – is a professional IDE (Integrated Development Environment) for application development using C or Assembler languages for PIC microcontrollers. MPLAB is a product of Microchip Inc.,

CCS – is a complete software environment for developing control programs in C language for Microchip's PIC (12,14,16 bit) microcontrollers. CCS is product of CCS Inc.

SCIENTIFIC COOPERATION

The DNA microarray facility at the Cancer Centre and Maria Sklodowska-Curie Memorial Institute of Oncology

Members of the Control Theory Group initiated a project that resulted in opening of the first high-density DNA microarrays laboratory in Poland and are co-managing research done there.

The DNA microarray facility at the Cancer Centre and Maria Sklodowska-Curie Memorial Institute of Oncology in Gliwice, which started working in September 2002, is the first microarray unit in Poland and one of the first in this part of Europe, opening this type of genomic research to many groups, both oriented toward basic research and for clinical ones. The establishment of microarray-based gene expression analysis with appropriate data mining facilities is a prerequisite for the research purposes and for the development of new diagnostic tools. Problems arising in cancer epidemiology may be addressed by microarray analysis, which can be done only providing a close cooperation between experts in oncology, mathematical modelling of dynamical systems, statistical analysis, image processing and computer science. The project fulfils this condition and simultaneously enables close cooperation with many centres in European Union from one side and in Central and Eastern Europe countries from the other, which will facilitate spreading of new technologies and knowledge over this part of the continent.

The project will catalyze interaction and speed up the process of application of microarray technology into various disciplines of medicine interested in molecular oncology. Sharing of the instrumentation and technical experience, including the most competent team of bioinformaticians for the evaluation of results, encouraging communication and exchange of knowledge will create an attractive and highly competitive interdisciplinary milieu that will be able to contribute to European research and clinical activities .

International grants

Members of the Group are involved in the researches within the framework of *NATO Collaborative Linkage grant „Gene Expression Data: Image Processing and Classification Algorithms*". Additionally, Professor A. Świerniak has been closely collaborating with coordinators of European ESF/PESC grant "*Using Mathematical Modelling and Computer Simulation to Improve Cancer Therapy*". Currently the Group is preparing a proposal for a 6th Framework Program together with its European partners.

Direct cooperation with other research groups

1. Cooperation with the Novosybirsk State Technical University, Russia, concerns control law synthesis for continuous dynamic systems based on localization and dynamic contraction methods,
2. Cooperation with L'Universite de Montreal, Canada, concerns the problem of robust control of complex uncertain systems with Markov jumps,

3. Cooperation with the Nottingham Trent University, Department of Computing, Real-Time Telemetry Systems Group concerns city traffic flows simulation and control,
4. Cooperation with Department of Statistics, Rice University, Houston concerns modeling and control of cancer cell population,
5. Cooperation with Baylor College of Medicine, Houston, USA concerns,
6. Cooperation with A/O ASIF Research Institute in Davos concerns modeling and control in biomedical systems,
7. Cooperation with Baylor College of Medicine, University of Texas, School of Public Health, Human Genetic Center, Houston, USA concerns genetic studies,
8. Cooperation with Universite de Pau, France, Weitzman Institute, Israel and Biomathematics Study Group at Vanderbilt University, Nashville, USA includes biomathematical modeling, control and estimation in cancer cell populations,
9. Cooperation with Institute of Oncology, Gliwice, Poland, concerns radiotherapy protocols for cancer cells and population genetics,
10. Cooperation with Southern Illinois University, Edwardsville and Washington University, St. Louis concerns biomathematical studies,
11. Cooperation with Center for Mathematics and Computer Science in Amsterdam concerns morphological image and signal processing,
12. Cooperation with Institute of Mathematics and Computer Science, Bulgarian Academy of Science concerns selected problems of computer vision,
13. Cooperation with Belarussian Institute of Cybernetics in Minsk concerns image processing in spatial information systems,
14. Cooperation with Lvov Technical University, Ukraine concerns the field of signal and image processing.

Student exchange

Member of System Engineering Group, Joanna Polanska, is the Faculty Coordinator of student exchange SOCRATES/ERASMUS programme and a memeber of the Committee for development of European Credit Transfer System (ECTS). Jerzy Mościnski, from Industrial Control Group, is the Institutional Coordinator of the programme. They are encouraging and organizing, with the support of Dean, all of student exchange between Faculty and the universities listed below. During last two years almost 200 students studied abroad supported by the financial aid of SOCRATES programme, University Rector and Faculty Dean.

1. Karel de Grote Hogeschool, Katholieke Hogeschool Antwerpen, Belgium,
2. Universiteit Gent, Belgium,
3. Vitus Bering Centre for Higher Education, Denmark,
4. Engineering College of Copenhagen, Denmark,
5. Technical University of Denmark, Lyngby, Denmark,
6. University of Southern Denmark – SDU, Denmark
7. Odense University College of Engineering, Denmark,
8. University of Oulu, Finland,
9. Turku Polytechnic, Finland,
10. Kemi-Tornio Polytechnic, Finland,
11. ICAM Groupe (Institut Catholique d'Artes et Métiers), France,

12. EIGSI, Ecole d'Ingenieurs La Rochelle, France,
13. Université de Valenciennes et du Hainaut-Cambrésis, France,
14. Institut Catholique de Paris, France,
15. Ruhr Universität Bochum, Germany,
16. Brandenburgische Technische Universität Cottbus, Germany,
17. Technische Universität Dresden, Germany,
18. Friedrich Alexander Universität Erlangen-Nürnberg, Germany,
19. Fachhochschule Ingolstadt, Germany,
20. Universität Koblenz-Landau, Germany,
21. Universität der Bundeswehr München, Germany,
22. Georg Simon Ohm Fachhochschule Nürnberg, Germany,
23. Universität Stuttgart, Germany,
24. Cork Institute of Technology, Ireland,
25. University of Iceland, Reykjavík, Iceland,
26. Universita degli Studi di Padova "Il Bo", Italy,
27. Politecnico di Torino, Italy,
28. Universita degli Studi dell' Insubria, Varese, Italy,
29. Technische Universiteit Eindhoven, NL,
30. Instituto Politecnico do Porto, Portugal,
31. Kungliga Tekniska Högskolan (Royal Institute of Technology), Sweden,
32. Coventry University, UK,
33. Nottingham Trent University, UK,
34. University of Bournemouth, UK.

Instrumentation, Systems and Automation Society

Member of Control theory Group J. Śmieja is the Adviser of Instrumentation, Systems and Automation Society) Student Section at Silesian University of Technology. The ISA (Instrumentation, Systems and Automation Society) Student Section at Silesian University of Technology was formed in June 2000. At present the section numbers 18 members and the Academic Adviser Dr Jaroslaw Smieja. Its aim is to enable the transfer of knowledge, exchange of ideas, professional development as well as enhance students' chances in the job market. Additionally, ISA Executive Committee approved funds to place materials in the Silesian University Library, creating ISA Knowledge Center at the University. Members of the section participated in competitions held for students and published results of their work in student journal EuroXchange. In 2001, The section was awarded the first prize for its website in competition held for European student sections and its team finished in the second place in the European competition for students.

ADDITIONAL INFORMATION

R. Gessing:

reviewer

Zentralblatt für Math.	since 1978
Mathematical Review	since 1988
IEEE Trans. on Automatic Control	since 1994
Automatica	since 1995
IEE Proceedings Pt D	since 1996
Int. J. Control and Computers	since 1996
etc.	

member of IFAC Committee on Large Scale Systems since 1994
member of the American Mathematical Society since 1988
member of the Editorial Board of Archives of Control Sci. since 1987
member of the Committee of Automation and Robotics of Polish Academy of Science since 1978
member of Scientific Board of Systems Research Institute of Polish Academy of Sciences. since 1999
member of Scientific Committees of several National and International Conferences.

A.Świerniak

reviewer

Zentralblatt für Math.	since 1978
Mathematical Review	since 1985
Boletin Sociedad Matematica Mexicana	since 1994
Journal of Theoretical Biology	since 1994
Mathematical Bioscences	since 1995
Journal of Biological Systems	since 1995
Nonlinear World	since 1996
Control and Cybernetics	since 1995
System Science	since 1982
Int. J. Control	since 1985
Proc. IEEE	since 1985

Associate Editor in:

Journal of Biological Systems	since 1995
Int. J. Applied Mathematics and Computer Science	since 1996

member of the American Mathematical Society since 1987
member of the Society Mathematical Biology since 1995
member of European Mathematical Society since 1994
secretary of the executive board of Silesian Division of PTETIS since 1991
member of the Program Committee of the international conferences "Mathematical Population Dynamics" since 1995
member of Steering Committee of the Copernicus CP94-0536 project: Concerted Action for Simulation and Support of East-West Collaboration in the areas of Microelectronics and Signal Processing BENEFIT, since 1994

K. Wojciechowski

reviewer

Machine Graphics and Vision since 1992

member of the executive board of the Polish Association for Pattern Recognition (associated with IAPR) since 1992
member of Silesian Division of Polish Association fior Theoretical and Applied Electrotechnics (PTETIS) since 1991
chair of the scientific board of Silesian Spatial Information Center, since 1996
member of the scientific board of the Institute of Theoretical and Applied Computer Science, since 1996

COMPUTER CONTROL GROUP

The research activities concentrate on:

- system identification and adaptive control,
- active noise and vibration control,
- microprocessor instrumentation,
- eye movement signal processing,
- system controllability,
- distance learning,
- constraint logic programming,
- data mining,
- expert systems,
- text independent speaker recognition,
- prediction methods.

Research on system identification and adaptive control
Software for system identification

J. Kasprzyk, J. Figwer

Part of the staff of the Computer Control Group headed is traditionally engaged in research on various aspects of system identification and its applications, particularly to adaptive control. As a result of this activities a software package for system identification called Multi-EDIP was developed and its scope is continuously enlarged; it is used in education and research and commercialised on a small scale. Multi-EDIP is a user-friendly application for Windows 9x/NT/XP that may be used to identify and validate the following models for scalar or vector time-series:

- parametric, stochastic, stationary as well as non-stationary models (AR, MA, ARMA and their integrated instances),
- deterministic models (polynomial trends, sinusoidal components),
- nonparametric models – correlation and frequency-domain models and single-input-single-output or multi-input-multi-output systems,
- parametric, stochastic, stationary as well as non-stationary models (ARX, ARMAX, control channel transfer function, FIR, output error model, etc.),

- nonparametric models – correlation and frequency-domain models (cross power spectral density, coherence, frequency transfer function etc.),
- neural models.

Multi-EDIP supports also data preparation, including:

- data checking and correcting (dealing with outliers, stationarity tests, statistical parameters, etc.),
- data editing (decimation, interpolation, taking out a sub-series of interest),
- data pre-processing (filtering, normalisation, removing a periodic component).

Multi-EDIP frees the user from doing any computer programming by providing full control of all functions and services through a system of windows and pull-down menus and by taking advantage of graphical opportunities provided by Windows. Besides it supports the user during model identification by:

- providing automatically the most appropriate numerical procedures for model identification and model validation,
- offering expert advice in choice of model structure and result validation,
- providing data-base capabilities to store and retrieve: data samples, results of processing data and identified models,
- offering services for accumulating identification experience by providing a set of defaults values for some parameters,
- providing a system of context sensitive helps.

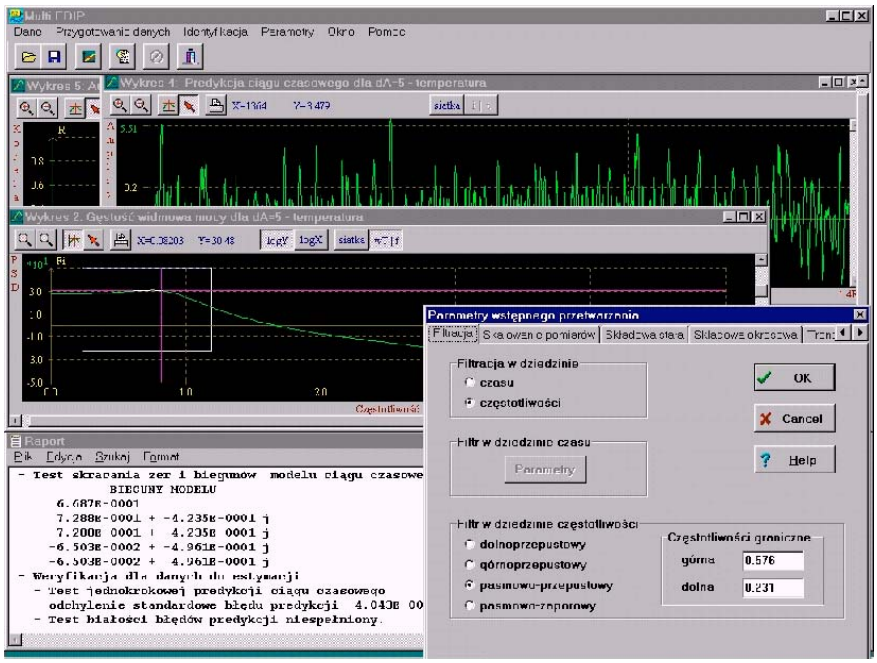


Fig. II.1. Multi-EDIP in action.

The Multi-EDIP environment has been exhaustively tested for a large number of laboratory projects by groups of students reading system identification and signal processing as well as in research on active vibration control and active noise control.

Research on random process synthesis and simulation

J. Figwer

Multisine time-series have been extensively studied. They are sums of discrete-time sines with amplitudes and phase shifts determined by a variety of methods, depending upon the purpose for which the multisine time-series will serve. Recently, their popularity has increased due to the possibility of generating them by numerically efficient software and hardware implementation of the discrete Fourier transform and opportunities offered by digital computers equipped with signal processors. One of the most recent applications of multisine time-series is synthesis and simulation of various deterministic signals and random processes with predetermined spectral or correlation properties.

This research concentrates on applications of multisine time-series for synthesis and simulation of wide-sense stationary scalar and multivariate one- and multi-dimensional random processes given by diagrams of their power spectral densities, where:

- synthesis means the process of establishing the discrete Fourier transform vector of multivariate multisine random time-series (1-D random process) or multidimensional (M-D) random process based on the corresponding power spectral density matrix of random process to be simulated,
- simulation means the process of numerically generating the corresponding time- series by performing an inverse FFT on the synthesised discrete Fourier transform vector.

The problem of synthesising and simulating random processes defined by their power spectral densities given in analytical form has been solved satisfactorily for rational 1-D power spectral densities. This approach is applied as an approximation for non-rational cases. In the case of multidimensional (M-D) random process given by its power spectral density, the problem of factorising the power spectral density is more complicated. It is well known that the M-D (M>1) power spectral density of rational form almost never has a rational factorisation. When the spectral factorisation problem is solved, the resulting random process is both synthesised and simulated as the output of a discrete-time linear filter excited by white noise. However, the analytical power spectral density parametric representation is hardly ever known. Very often the power spectral density of the time-series to be simulated is given only by a non-parametric representation, e.g. as diagram.

This research presents an approach to the problem of numerically synthesising and simulating wide-sense stationary time-series for which only a non-parametric power spectral density representation is known. In the presented approach the non-parametric power spectral density is approximated by a periodogram of multisine time-series with deterministic amplitudes chosen so that for a given number of equally spaced frequencies from the range $[0,2\pi)$, the periodogram of multisine random time-series is equal to the original power spectral density. The periodogram may be used in turn to construct the corresponding discrete Fourier transform vector provided the phase shifts for each sine component are chosen. It is well known, that any periodogram matrix corresponds to infinitely many different time-series, which differ by choices of phase shifts. It is demonstrated, that in order to get stationary ergodic random processes, the phase shifts should be chosen with some well defined random properties – they should be uniformly distributed in the range $[0,2\pi)$. This concludes the synthesis part of the

procedure. To simulate the synthesised time-series, the discrete Fourier spectrum with such chosen phase shifts is transformed into the time-domain using the inverse Fast Fourier Transform. Using this approach a broad range of scalar and multivariate random processes may be synthesised and simulated provided their power spectral density matrices are known. Realisations of the random phase shifts needed to synthesise and simulate realisations of the multisine approximation may be obtained using classical uniformly distributed random number generators. An interpretation of multisine time-series definition as a non-linear transformation of the corresponding phase shifts allowed proposing a new approach to generation of these realisations. This transformation is called a multisine transformation. It exhibits chaotic behaviour. Using the multisine transformation realisations of multisine time-series are calculated recursively: the phase shifts needed to synthesise and simulate *N*-sample multisine time-series are constructed using *N/2*-sample multisine time-series simulated in the previous iteration.

Multidimensional random processes given also by power spectral densities may be synthesised and simulated in the same way as 1-D random processes. The main building block in this there is an M-D multisine random process consisting of a sum of M-D sine components with deterministic amplitudes and random phase shifts.

The attractiveness of the proposed multisine approach to wide-sense stationary random processes synthesis and simulation has many reasons:

- there is no need to solve spectral factorisation problem for a given power spectral density to calculate the corresponding parametric approximation needed for simulation,
- the time-series or multidimensional random processes may be precisely defined in the frequency-domain, which is of importance for a number of applications,
- the frequency-domain definitions are used directly to generate, by means of any inverse discrete Fourier transform algorithm, the simulated time-domain realizations which satisfies the ergodic hypothesis and are asymptotically Gaussian,
- it may be used for nonparametrically defined wide-sense stationary random, rational and nonrational, scalar and multivariate time-series or multidimentional random processes, for which only the power spectral density representation is known,
- it may be used to generate various types of scalar and multivariate white noises, which turn out to have better properties than those generated by other means, e.g. congruential generators,
- it gives an opportunity to reduce radically simulation effort by a simulation time-scale contraction, which is a new proposition in Gaussian random process simulation,
- there is a direct extension of the proposed random process synthesis and simulation method to generation of wide-sense stationary continuous-time band-limited random signals, defined also by their power spectral densities.

Multisine approximations of wide-sense stationary scalar and multivariate random processes obtained by this approach have discrete spectra. However, the original processes have continuous power spectral densities. It turns out that by fulfilling certain conditions on sampling in the frequency domain, the approximation of continuous spectra by discrete spectra is not resulting in loss of information.

Research on system identification and adaptive control
Process identification with multisine excitations

J. Figwer

This research concentrates on methods of nonparametric and parametric, linear and nonlinear model identification for single- and multi-input linear, discrete- and continuous-time systems, which produces upper bounds on identification errors by using: a specially designed excitation of the form of scalar and multivariate multisine excitation with orthogonal elements.

The identification experiment with multivariate multisine excitation is designed in a special way. The excitation is repeated after all transients have decayed. In order to estimate models, continuous-time signals are represented by sets of their samples taken at discrete-time instants. It implies that model identification based on finite data sequences can be made both more accurately and faster:

- the increase of accuracy is due to removing from data used for identification all transients. The data are thus characterizing steady state output signal for multisine excitation,
- the saving of time and computation is due to the following facts:
  - all partial SISO outputs are orthogonal to each other and the problem of joint multi-input system identification may be decomposed into independent SISO and separate disturbance-channel identification problems,
  - properties of multisine excitations simplify mathematical formulae for upper bounds on Markov parameters and frequency response identification errors,
  - derivatives and integrals of the continuous-time band-limited multisine signals which are necessary for parameter estimation can be calculated from samples of excitation signals by using discrete Fast Fourier transform algorithm,
- the proposed identification method allows to estimate models of continuous-time systems directly from samples of input and output signals without identification of auxiliary discrete-time models.

The decomposed SISO identification problems are solved using classical identification methods with a focus on identification error upper bounds. The proposed bounds on identification errors are calculated directly from samples of input and output signals without special interpolation.

Research on system identification and adaptive control
Limited Authority Adaptive and Predictive Control

Z. Ogonowski

Limited Authority Adaptive Control (LAAC) concept introduced by M. Grimble in 1997 has been applied to PID controller and provided unexpectedly good control quality. The main advantage of this concept is reduction of adaptation to as small number of controller parameters as possible. The research conducted by the Computer Control Group demonstrated that in the context of PID control the only parameter to be

adapted is the controller gain, while reset time and derivative time remain constant after being pretuned according to nominal control system conditions. However, the LAAC PID control is not a simple adaptive algorithm because the full model has to be identified to calculate proper value of the controller gain. So-called indirect adaptation is then necessary and the prospective simplification of the adaptive system announced by Grimble is not provided. Reduction of the parameter calculation is much to little when comparing with computation efforts needed for on-line model adaptation. On the other hand it seems very promising gain-only adaptation in PID control. Thus simplified adaptation methods are needed.

Research has been focused on different methods of simplification of LAAC PID control: polynomial methods, artificial neural models methods and gradient methods. The methods have been compared using specially designed bench-marks. Results obtained proved that the algorithms improves significantly the control quality if the characteristics of the plant changes or the plant is non-linear and operation point changes.

LAAC concept has been also developed for pole placement technique. The main advantage of the pole placement in the adaptive control context is the possibility of direct adaptation which is well known to be faster and easier to implement when compare with indirect adaptation. The research conducted by ICG proved that parameters of so called predictive model being the base of direct controller adaptation can be easily separated and the only part of the parameters have to be updated. Thus, LAAC approach can be used. In the standard direct adaptive control with pole placement a sophisticated difficulty arises: in order to identify controller parameters a part of the plant model has to be known otherwise the predictive model is unidentifiable. The problem is solved using specially designed signal filtration. Research conducted by ICG demonstrated simplicity and robustness of the algorithms proposed.

The research conducted by ICG referred also to adaptive receding horizon predictive control. This approach is an optimising control where criterion index is any norm of a distance between predicted output of the closed loop system and a reference trajectory of the output over a finite horizon. If a model of the plant is linear and no constrains are imposed on the control signals then the solution of the problem can be found analytically, and the control algorithm is established in a simple form of transfer function or difference equation. A concrete form of this algorithm depends on the model type and additional assumptions concerning future control scenario. If the model of the plant is non-linear or constraints are imposed on the control signal then analytical solution of the minimisation problem no longer exists. This is probably the most important drawback of the predictive control because minimisation task has to be solved numerically in every sampling period. Additional analytical problems arise because the horizon recedes. This makes stability and performance analysis difficult even in the linear case.

Important theoretical results concerning non-linear predictive control has been reported in the last decade. Assuming that the solution of the minimisation problem is known, the closed loop system stability and the performance issues can be analysed. However, this results are leaving out of account numerical problems arising in minimisation of the criterion function: in every sampling period hard non-linear minimisation problem with constrains has to be solved. The major difficulties come from the following: (a) non-linearity of the model can lead to non-convex programming, (b) number of decision variables depends on the length of prediction horizon, (c) constrains are imposed on controls and states of the system. These results have only

theoretical value and are completely unimplementable. There is a strong need for simplified approaches leading to control algorithms of the following features: (a) approximation of the optimal solution, (b) models are simple and easily interpretable (e.g. non-parametric models), (c) control algorithms are implementable in standard microcontrollers.

The research conducted by ICG based on an idea of merging the structure of linear controller given with non-linear model. The only free response prediction is necessary to be obtained from the model. Control algorithm uses free response prediction to calculate control increments. Controller parameters are tuned according to the reference model. It has been proven that dependence between controller parameters and measured signals can be described with linear equation. This allows to use idea of direct adaptation. However, data used by identification procedure comes from non-linear world: free response prediction comes from non-linear model and measured output of the system comes from non-linear plant. In this sense the resulting control algorithm is non-linear oriented.

The idea of using linear predictive controller to non-linear plant has been applied to control evaporation process and acryl-nitryl copolymer production process. Efficiency of the resulting control systems has been reported. The only drawback was little influence on the closed-loop system dynamics. Thus, the concept of pole placement has been used. It has been proven that under weak assumptions it is always possible to locate poles of the closed-loop system in arbitrary places using predictive controller. Linear parametric model is used to compute necessary variables for identification issues. Instead of the pole placement the reference model concept can also be used. Another advantage of the approach is inclusion of nonparametric models enabling to use non-linear models instead of linear parametric models. Fig.II.2 and Fig.II.3 present results of control of the evaporation system (R.B.Newell and P.L. Lee *Applied Process Control. A case study.* Prentice Hall. 1989). One of three state variables, the product composition is shown after set-point change from 50% to 70% of the range in time 0 min and down to 40% in time 100 min. Fig.II.2 presents the response of nonlinear predictive control; Fig.II.3 presents the response of linear predictive control (GPC).

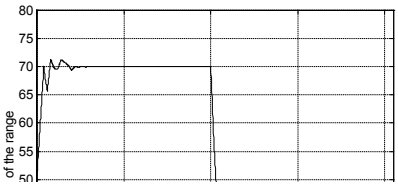


Fig. II.2 Nonlinear predictive control of the evaporator system.

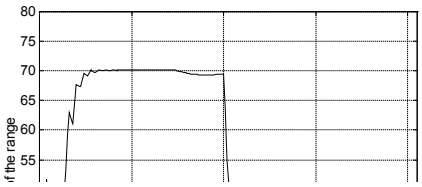


Fig. II.3 Linear predictive control of the evaporator system.

Both controllers are adaptive. It is demonstrated in the figures that the convergence and speed of the response is much better in nonlinear case.

Research on system identification and adaptive control

Non-linear minimum-variance control

E. Bielińska

A key issue is a development of an efficient adaptive control algorithm for disturbed non-linear objects. The case where power spectrum of disturbances contains mainly high frequencies is considered.

For high frequency disturbances, which cannot be suppressed by conventional controllers, analogous or digital ones, there exist a group of control algorithms that avail themselves of prediction of the disturbances. The prediction is made on the base of the stochastic model of the disturbances that may be observed in the output, when the input and the measurable disturbances are fixed. The control algorithms are designed so to minimise the variance of a control error. To derive the controller and input-output model and a model of disturbances should be assumed. Mostly is assumed that both models are linear. This remains valid when one is dealing with a set point control. However, in other cases, when linearity of a system has been assumed a'priori, final control results may be worse than expected ones. Hence, it is suggested, that as well the input-output model as the model of disturbances are non-linear.The generalised non-linear model is proposed and with this assumption theoretical basis for non-linear direct and adaptive MV control of non-linear models with bilinear model of disturbances is presented.

Computer program **ADAP**, that has been developed, afford possibilities for wide simulation of linear and non-linear objects disturbed in different ways and working under a number of circumstances.

Option **Plant** enables users to model an input-output object,
Option **Controller** makes creating linear, non-linear, direct or adaptive controllers possible. * Option **Signals** is applied to model linear or non-linear disturbances as well as to form a reference value,
Option **Identification** enables users to find a model of the object when the structure of the model is assumed,
Option **Runtime Change** enables users to change object's or controller's parameters during the simulation.

Simulations that have been carried out confirmed that proposed rules are useful in designing effective non-linear control algorithms as well direct as adaptive ones. When a controlled object is distorted by non-linear disturbances, that may be modelled either as bilinear time series or as linear ones, than taking into consideration this second possibility gives less output error variance. The improvement of control is usually from a few to a dozen or so percent. In general, it depends on the ratio of white noise variation in the bilinear model of disturbances to the white noise variation in the linear one. Final decision always belongs to the user. He should decide if the expected improvement in the output's variance is worth using a little more complicated non-linear control algorithm. However, it should be noticed that for large scale production even a few percent growth may be important.

Research on system identification and adaptive control

Speech signals analysis, identification and synthesis

E. Bielińska

The research is concerned with application of parametric time series models for speech modeling and synthesis. Experiences confirmed, that non-stationary, linear auto-regressive models can be applied for speech modeling and then for speech synthesis. Non-stationary auto-regressive model consists of a number of partial auto-regressive models either of equal or of different degrees. The degree of each partial auto-regressive model as well as a time in which the partial model remains valid should be chosen experimentally. It results from the experiments that the number of different AR models, that are required for modeling of speech signal lasting 1 sec, equals 15-30. Degrees of partial models change from 5 to 15. Hence, the total number of data that are to be assumed is quite large. Therefore one can ask if it is worth to replace the non-stationary AR model with some other models.

Laboratory stand, together with respective computer program ACOUSTIC, were designed to make possible speech signal acquisition, preprocessing, identification, modeling and synthesis. Laboratory stand consists of tape recorder, computer IBM PC386 equipped with Programmable Laboratory Card PLC 818, amplifier and loudspeakers. Speech signal from type recorder may be sampled with frequency of 50 kHz and then it may be preprocessed in order to obtain its parametric model. The model may be actuated with white noise series and after subsequent preprocessing it may be send to the loudspeakers or to the tape recorder in order to listen to the synthesized sound and compare it with the original one. As the sampling frequency of 50 kHz is too large for signal to computer analyze, it is necessary to decrease it to compromise on the number of data to be analyzed and the quality of sound. It was found out by way of experiment that sampling frequency of 5 kHz still let us understand the meaning of the speech signal. Hence, the speech signal is converted according to the scheme (Fig.II.4).The speech signal collected with frequency of 50 kHz is then filtered off in order to eliminate all frequencies above 2.5 kHz. Next the number of samples is decreased, by choosing every tenth sample from the prefiltrated signal. Then the signal may be preprocessed in one of the chosen by the user way. If the signal's model is found out it may be applied to reconstruct the speech signal. Next its sampling frequency should be increased, for instance by way of interpolation, then again the frequency above 2.5 kHz is filtered off and the signal may be sent to the loudspeaker.

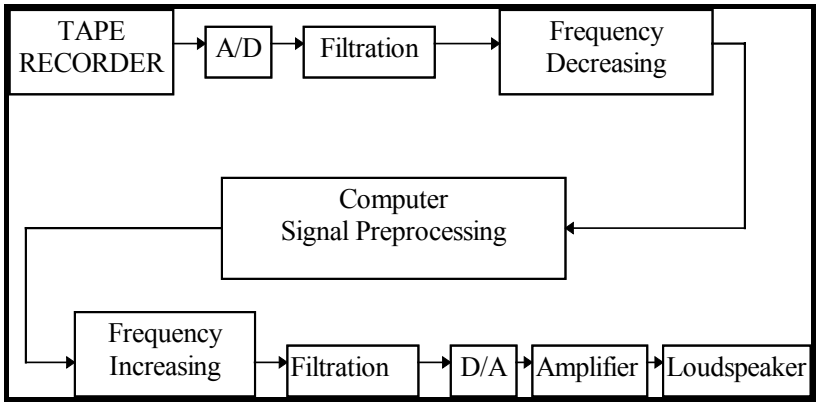


Fig.II.4 . Scheme of the laboratory stand.

A specially dedicated computer program ACOUSTIC enables users to preprocess the signal in a chosen way. The following options and procedures are available:

- procedures of signal's visualization,
- procedures of signal's edition,
- calculating the power spectral density and auto-correlation,
- procedures of linear stationary AR, non-stationary AR and bilinear signal's model identification,
- reconstruction of speech signal on the base of identified model.

Linear non-stationary AR models are identified using lattice-ladder method while bilinear models are identified using modified ELS method.

Using the laboratory stand described above the number of experiments were carried out in order to analyze and reconstruct the single speech sounds and words. It appears that:

- The single speech sounds that can be reconstructed on the base of linear stationary AR model can be as well reconstructed using bilinear model with total number of coefficients smaller than for AR model,
- Linear stationary AR model is not sufficient for word or sentence reconstruction,
- Non-stationary linear AR models are suitable for reconstruction of single speech sounds, words and sentences. Reconstructed signal is comprehensible. Number of coefficients of the non-stationary AR models depends on the length of the speech signal and is equal to the sum of all partial models' coefficients.

Signals reconstructed on the base of bilinear models are less comprehensive than the ones identified on the base of linear non-stationary AR models.

Research on text independent speaker recognition

E. Bielińska

The objective of speaker identification is to identify a speaker among set of speakers, based on the individual utterance. While text-dependent systems require that an utterance pronounced by a test speaker be identical with the speech used for training session, text-independent systems should recognize speaker regardless of his utterance. In the speaker identification task a speech utterance from an unknown speaker is analyzed and compared with speech models of known speakers. The unknown speaker is identified as the speaker whose model best matches the input utterance. The paper focuses on the text-independent speaker recognition.

Final results of speaker identification depends mainly on features extraction and a method chosen for speaker recognition. Process of speaker features extraction consists on obtaining such informative and representative parameters of a speech signal that mostly characterize the speaker, and not the meaning of the utterance. These features should be invariant with regard to one desired speaker while exhibiting a large deviation from the features of an impostor. It should be pointed out that in various conditions a certain feature set gives various performance and so far no feature set has been found to allow perfect classification for all applications.

Speech signals are generally non-stationary. The speech signal, generated by the excitation of the vocal tract, is composed of two types of basic waveforms: voiced and unvoiced sounds. It is taken as an assumption, that a speech segment over a small time

interval can be considered as a stationary signal. Hence, the registered speech signal may be segmented into separate frames, containing 10-20 msec fragments of speech. The signal in frames may be modeled as an output of a linear stationary filter excited in the input by a white noise signal.

Short-term analysis of the signal in frames allows extracting the personal speaker features. A set of short-term training feature vectors can be used directly to represent the essential characteristic of that speaker. However, such a direct representation is impractical when the number of training vectors is large, since the memory and amount of computation required become prohibitively large. Therefore, attempts have been made to find efficient ways of compressing the training data. The important problem is which ones of a great deal of parameters, that describe speech signal should be chosen as personal speaker features.

As an example set of 14 cepstral parameters for 13 training speakers generating 6 different utterances are shown in Fig.II.5.

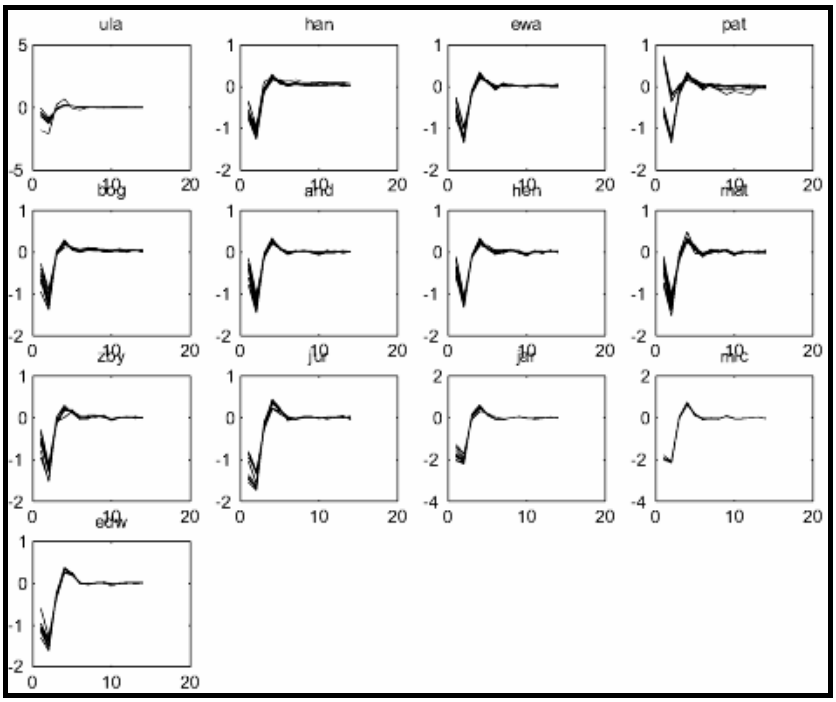


Fig. II.5. Set of 14 cepstral parameters for 13 training speakers generating 6 different utterances.

As an another example, *n* pairs of poles, which most frequently repeated in frames during the training utterance, were chosen as the features that characterize the speaker. Extracted Set of poles extracted in training (o) and testing (*) sessions for 13 speakers that have generated 6 utterances are shown in Fig. II.6.

The research is concerned with application cepstral and LPC methods for speaker identification. The crucial point is extracting speaker information from the speech signal. Besides two principal methods, filter bank analysis and linear predictive coding, another methods of extracting speaker identification are considered. Especially, a method based on poles classification is tested, as it proved to be efficient in speaker information extracting.

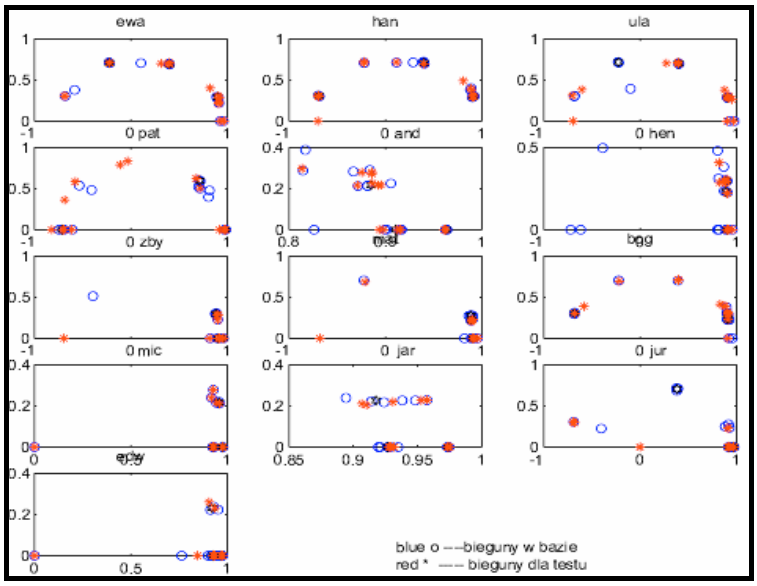


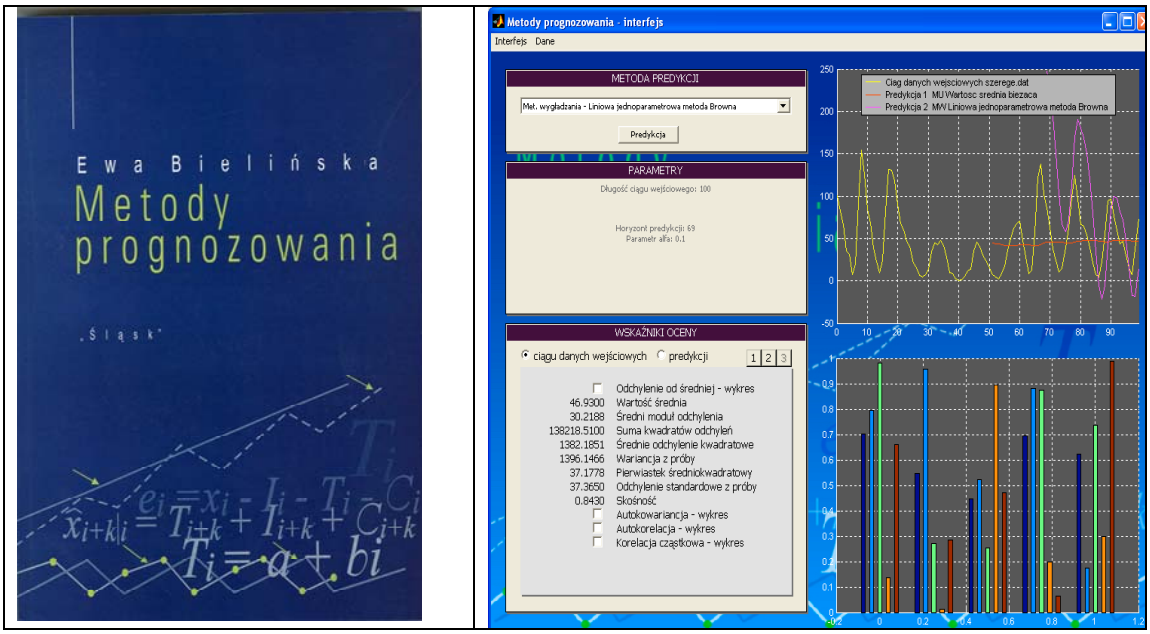
Fig. II.6. Set of poles extracted in training (o) and testing (*) sessions for 13 speakers that have generated 6 utterances.

Time series analysis and prediction

E. Bielińska

In this project different methods of signal prediction are developed and tested, and computer systems for signal analysis and prediction are developed.

Especially, possibility of prediction of non-Gaussian stochastic time series with the use of elementary bilinear time series models is considered. Concept of an elementary bilinear time series model is developed, and stochastic and predictive properties of the model are considered.



Virtual Microphone Control systems
for generating zones of quiet at desired locations

M. Pawełczyk

In active noise control a secondary sound source (sources, in general) is used to cancel low-frequency noise upcoming from original primary sources using the phenomenon of destructive interference. Local active noise control near the secondary source deserves particular interest. It is technologically feasible and acceptable. It requires small energy amount and therefore is also economically efficient. Because the distance between the real microphone providing information on the attenuation results and the observation point is usually nonzero and can vary in time the zone of quiet generated at the real microphone can poorly propagate to the observation area, where, by assumption, the user's ear is located, particularly for higher frequencies.

Besides performing noise reduction at the position of the real microphone, the secondary sound operates at the same time on the disturbance at the position of the user's ear. In the worst case this can result in sound reinforcement at that position. In many applications placing another microphone directly at the ears is not accepted. It is then justified to make efforts to design a dedicated system capable to minimise the mean-square value of the signal at the desired location while performing measurements of sound interference results at another location using a real microphone. This can be done by employing the general idea of Virtual Microphone Control (VMC) systems (see Fig. II.7). Within the work reported VMC systems in three different structures have been designed.

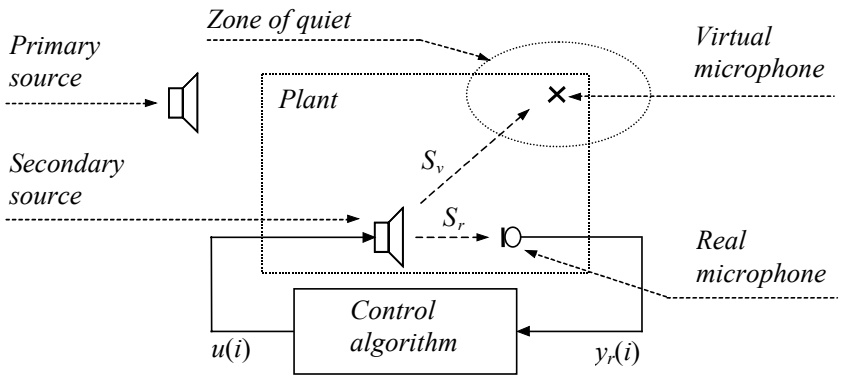


Fig. II.7. The idea of VMC system.

The first one, VMC1, has the form of a classical feedback with the controlled signal being the input to the control filter. The second, VMC2, and the third, VMC3, structures are similar to that of the Internal Model Control system, where estimate of the disturbance drives the control filter. Therefore, if the real path (path from the secondary source to the real microphone) is well modelled these structures exhibit features of a feedforward system and therefore appropriate design methods can be applied. The third structure has been additionally equipped with a filter that stores knowledge about the noise being controlled and is used to work out a desired signal for the residual signal measured by the real microphone. This structure has been designed to cope better with stationary noise. In turn, in VMC1 and VMC2 structures an estimate of the residual signal at the virtual microphone is controlled.

For all the VMC structures optimal control filters, minimising mean-square value of the considered signal have been designed first, using the polynomial, frequency-domain and correlation-based approaches.

Next, adaptive VMC systems with update of control filters parameters with the Filtered-reference (known as the FXLMS) algorithm have been considered. Phase conditions for convergence have been derived. It has been emphasised that the adaptive VMC1 system can operate poorer than the other systems because the correlation between the input to the control filter and the disturbance becomes degraded when the adaptive algorithm tends to converge. VMC2 and VMC3 systems are free of this problem provided the modelling of the real path is sufficiently good. The convergence condition for VMC3 is, however, weaker than that for VMC2.

Active control of acoustic noise in a headrest system

M. Pawełczyk

The work with active headrest system concentrates on creating local zones of quiet at the ears of a person occupying a chair. Headrest of the chair is therefore equipped with loudspeakers generating the secondary sounds for both channels as well as microphones sensing interference effects. Shape and arrangement of the necessary components of the prototype of the active headrest have been carefully designed not to annoy the user and become closer to a solution acceptable by the market.

Fig. II.8. The active headrest system.

Improvement of the user's acoustic comfort has become a challenging problem. The acoustic comfort can be considered in two equally important counterparts – the attenuation level and dimensions of the areas of highest attenuation (zones of quiet). Therefore, obtained results are presented graphically as distribution of attenuation areas.

It has been proven that allowing two secondary sources to operate (mainly) on one channel significantly extends the zones of quiet, which, contrary to the simpler structure with one secondary source per channel, reach the ears. Moreover the system permits head movements to some extend. To allow the user much more freely moving without rapidly leaving areas of high attenuation, the idea of virtual microphones has been applied and the designed algorithms have been implemented. They generate indeed the

zones of quiet at the desired locations, i.e. the ears. Moreover, their dimensions are large enough to cover significant areas. Employment of more virtual microphones for the same channel extends the zones (see Fig. II.9). Therefore, the subjective impression perceived by the listener is very positive. All the systems developed operate very stably. Even quite significant head movements, or, moreover, exchange of persons sitting in the chair during working of the algorithms does not lead to divergence of control filter parameters.

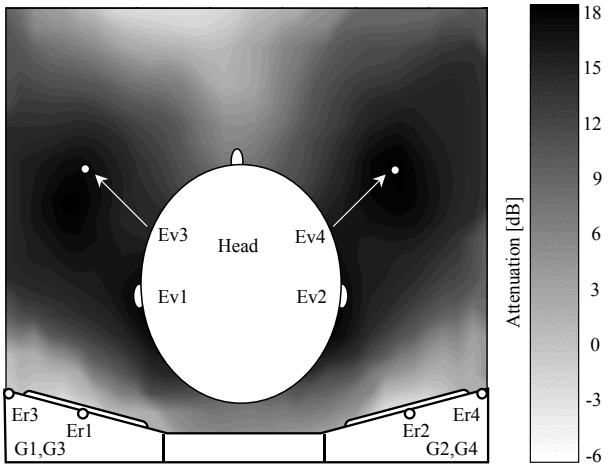


Fig. II.9. Distribution of attenuation areas for a tone of 250 Hz.

Active control of acoustic noise in a phone

M. Pawełczyk

Phones are currently common devices used for communication. However, in many places, for instance on a rush street, the communication suffers from excessive noise. Phones seem to posses basic components required for active control, like a microphone and a loudspeaker with amplifier. However, to cope with low-frequency industrial and road noise, the receiver has been provided with a loudspeaker, well passing frequencies from 60 Hz on. An additional ¼" microphone has been located perpendicularly to the loudspeaker (see Fig. II.10). Noise control problems in 'active phone' are similar to some extend to the problems observed in active headsets, where much better performance can be obtained with analogue than digital control for industrial and road noise. However, contrary to active headsets, the receiver in a phone is not well sealed to the head but rather located a few centimetres away. The zone of quiet generated for the frequency band considered poorly propagates to the user's ear. Therefore, appropriate analogue controller structure with a virtual microphone has been proposed that shifts the zone of quiet to the desired location, i.e. to the middle ear. Parameters of the controller are found by solving an optimisation problem. The main goal is formulated to assure highest attenuation at the virtual microphone over required frequency band. The constraints guarantee assumed stability margin and do not allow to reinforce the noise beyond the band of interest over acceptable threshold. The overall system has been experimentally verified.

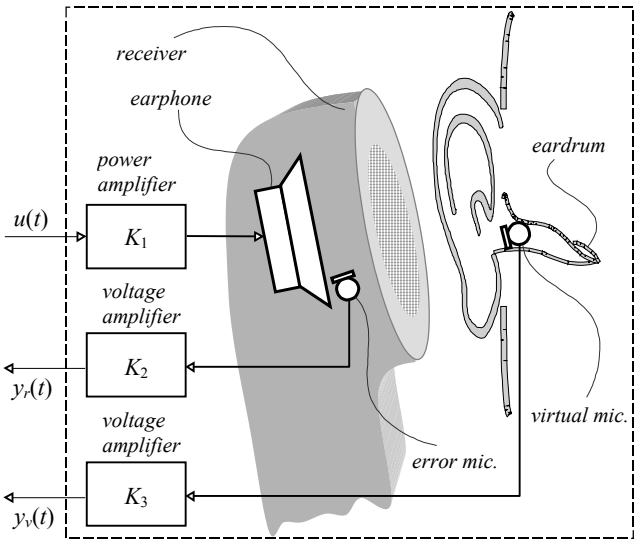


Fig. II.10. Active phone.

Contrary to most of the active noise control applications, where the desired signal is zero, corresponding to silence, in case of the active phone the desired signal is the speech transmitted from the far-end user. Therefore, additionally a feedforward filter compensating for influence of the noise control system has been designed and implemented for improving intelligibility of the distorted speech. Exemplary results of control of a road noise are presented in Fig.II.11.

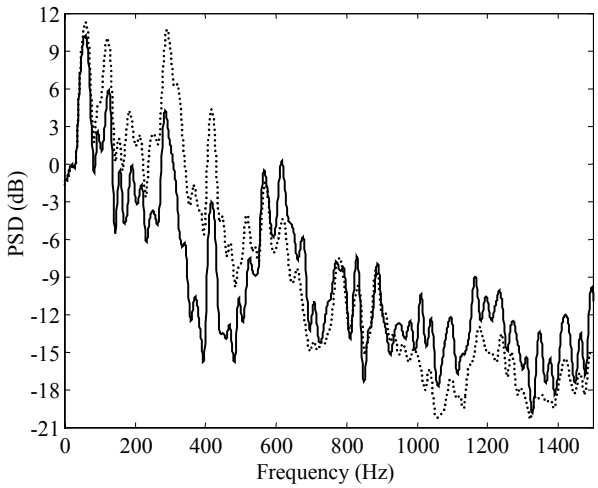


Fig. II.11. Estimates of power spectral density of a road noise reaching the middle ear before (dotted) and after (solid) active control.

Polish Version of Supervisory Control and Data Acquisition system iFIX v3.0 with Technical Documentation

R. Jakuszewski, M. Pawełczyk

Polish version (including translation, verification and supplement) of the iFIX v3.0 system made by GE Fanuc Intellution company has been developed. This version has

been published on CD by AB Micro company, Warsaw, and consists of the following items:

- 128 programmes of the iFIX system – total 128 MB,
- context help of the iFIX system and VBA (*Visual Basic for Applications)* programming language,
- technical documentation in the form of textbooks (18 textbooks – total 2141 pages) and compact disk.

The iFIX system is a leading Supervisory Control and Data Acquisition (SCADA) software all over the world. It fulfils all functions of visualization, data acquisition and supervisory control of technological processes in industry. iFIX enables precise monitoring and parameters audit of manufacturing processes as well as devices and supplies, in order to increase output and production flexibility, decrease waste of materials, enhance production quality, shorten the time for new products to appear on market, and enlarge production profitability. The system contains all tools necessary for quick application development of any type and size, beginning with individual HMI (*Human – Machine Interface*) station, and finishing with complex multi-station SCADA system network. iFIX uses object-oriented core iCORE, which joins innovative technologies of Intellution and Microsoft companies to programme industrial automation systems - DNA - M, OPC, COM / DCOM, ODBC / SQL, VisiconX, DDE, Backup & Restore, Plug & Solve, Secure Containment. The built-in VBA programming language additionally gives unrestricted possibilities for controlling industrial processes and data handling. iFIX offers the protection of data access by using extended security systems of Windows NT/2000/XP as well as enables full redundancy in LAN network and emergency switching between SCADA servers.

There are many applications over the world using mechanisms included in this system to control and supervise thousands of manufacturing processes in chemical, food, pharmaceutical, electronic, machine, metallurgy and power industries and in many other branches. There are over 2000 such applications in large plants in Poland. Students of the Silesian University of Technology also use the developed system in SCADA laboratories as a basic tool for preparing their M.Sc. theses and during lectures related to SCADA subjects (see Fig. II.12).

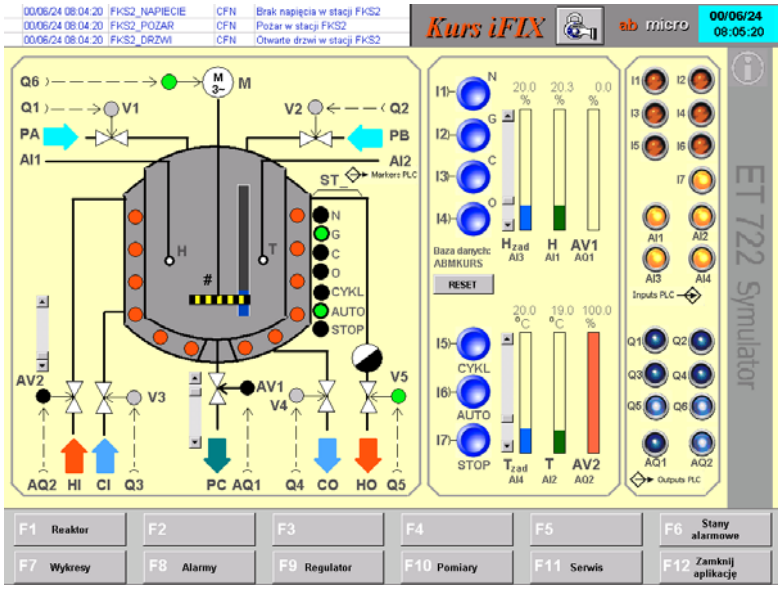


Fig. II.12. Examplary screen of the iFIX v3.0 system.

Research on on-line digital signal processing
Active noise control in an acoustic duct

D. Bismor

Passive methods of noise control are not adequate in many applications, especially for industrial (low frequency) sounds. In an effort to overcome problems with sound attenuation, active noise control (ANC), in which additional secondary sources are used to cancel noise from the original primary sources (according to Youngs interferation principle), has received considerable interest and has shown significant promise. Both acoustic and electric paths usually vary in time so ANC algorithms are required to have adaptation features. One of possible applications of ANC is control of low-frequency noise in air-conditioning ducts and exhaust pipes. These objects are well approximated with the acoustic duct.

The acoustic duct station schematic diagram is presented on Figure II.14. The duct is made out of wood, it is four meter long, and of 20x40 cm in diameter (Fig. II.13). It must be emphasised that in order not to idealise the laboratory conditions the duct was not covered with sponge; neither inside, nor outside. The acoustic duct station block diagram is presented on Fig.II.15.

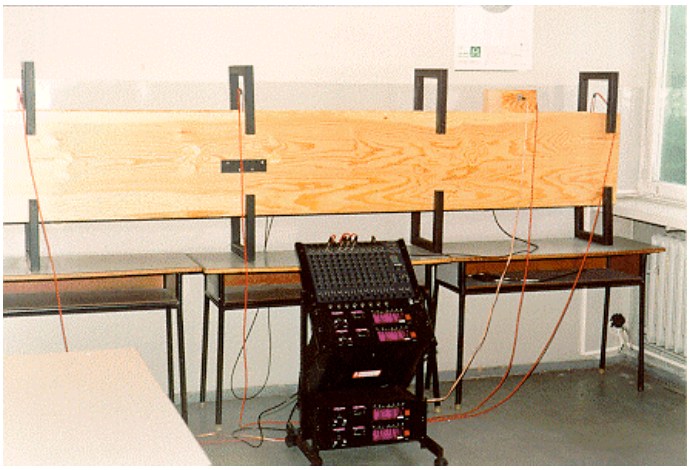


Fig. II.13 Acoustic Duct Active Noise Control Laboratory.

The signal generated by the noise source, propagating downstream the duct is sensed and measured by the microphone M1. Then, it passes the acoustic path between microphone M1 and loudspeaker L2, denoted as $P1(z^{-1})$. Right below the loudspeaker L2 the acoustic summing junction is located: this it the point where the noise meets the antinoise y'(i), generated by the control algorithm. The acoustic summing junction is separated from the error microphone M2 by the acoustic path $P2(z^{-1})$. Unfortunately, the antinoise propagates not only downstream the duct, but also upstream, constituting what is called acoustic feedback. As a result every algorithm, even designed as purely feedforward, suffers from such feedback drawbacks, as e.g. instability. The feedforward control algorithm is represented by transfer function $F(z^{-1})$ while feedback control algorithm is represented by $R(z^{-1})$. Note also that transfer functions $M1(z^{-1})$ and $M2(z^{-1})$ contain not only microphone transfer function, but also preamplifier, anti-aliasing and A/D converter transfer functions. The transfer function $S(z^{-1})$ contains transfer functions of D/A converter, reconstruction filter, amplifier and loudspeaker.

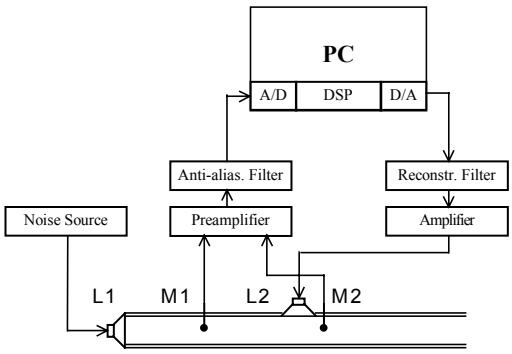


Fig. II.14 Acoustic Duct Active Noise Control Station Schematic Diagram.

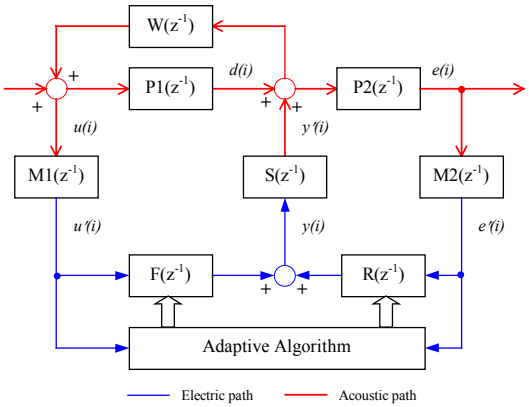


Fig. II.15 Acoustic Duct Active Noise Control Station Block Diagram.

The goal of the research was to show that control methodology (feedforward and feedback control) may be used to solve active noise control problem in an acoustic duct relying only on identified models. This goal was attained by performing detailed identification of electro-acoustic paths shown on Fig.II.15 and by implementing a wide range of both feedforward and feedback control algorithms. The algorithms included:

- feedforward control using Finite Impulse Response (FIR) filters, with adaptation with Recursive Least Squares (RLS) and Least Mean Squares (LMS) algorithms,
- feedforward control using Infinite Impulse Response (IIR) filters (also with adaptation provided by both RLS and LMS algorithms),
- feedforward control using neural networks,
- feedback control using Internal Model Control and Minimum Variance Control algorithms,
- hybrid control, containing both feedforward and feedback controllers.

The most satisfactory results for feedforward control have been obtained with correlation modification of FXLMS algorithm applied to adaptation of FIR filter and with constant trace modification of RLS algorithm applied to adaptation of FIR filters. The RLS algorithm provided better time performance (faster convergence). However, due to its complexity it was impossible to use as high filter lengths as with simpler FXLMS algorithm.

During development of feedforward control algorithms big influence of reconstruction filters (see Fig.II.14) has been discovered. Namely, the absence of reconstruction filters resulted in considerable difference between active noise control algorithm performance measured with M2 microphone (and thus observed by and influencing adaptation algorithm) and with sound level meter. The most satisfactory results for feedback control have been observed with Minimum Variance Control algorithm. On the other hand, the Internal Model Control Algorithm showed performance within low range frequency, where the active control is the most important. To some disappointment, the hybrid algorithms did not show better performance than feedforward control. However, it is believed (and still remains to be tested) that this type of control provides better propagation of silence zone along the duct.

Further development of active noise control for acoustic duct has been inspired by problems with acoustic feedback phenomenon (see transfer function $W(z^{-1})$ on Fig.II.15). So far it was cancelled by appropriate processing of reference signal (so-called feedback neutralisation). Such method involves estimate of electro-acoustic

transfer function of acoustic feedback. As this estimate may be inaccurate, it may introduce error to the processing.

Virtual unidirectional source of sound (VUSS) is another approach to the problem of acoustic feedback. The idea of VUSS is to use adaptive signal processing algorithm to drive two loudspeakers in such way that the sound produced with them virtually propagates only downstream the duct. Virtually means that in fact the sound generated by each loudspeaker propagates in both directions, but the processing algorithm assures that the sound waves propagating upstream the duct are actively cancelled by themselves, while those propagating downstream the duct are amplified.

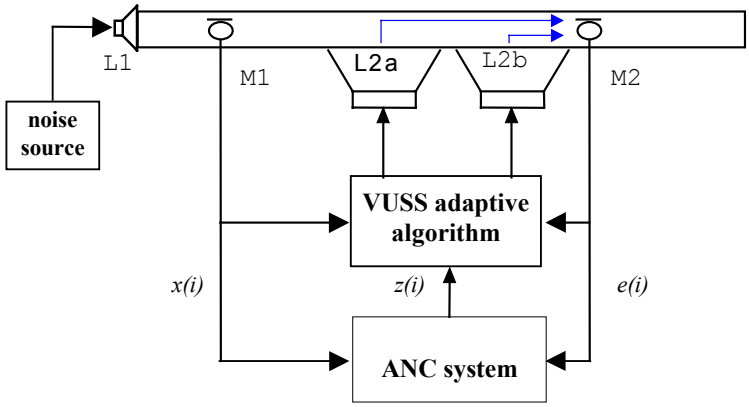


Fig.II.16. The ANC system containing Virtual Unidirectional Source of Sound.

The overview of the virtual unidirectional source of sound system is shown on Fig.II.16. The process value for the VUSS algorithm is the control value produced by the active noise control system. In this case both VUSS algorithm and ANC algorithm use the same microphones M1 and M2. The virtual unidirectional source of sound algorithm uses multi-channel FXLMS algorithm to adjust appropriate adaptive filters it contains. Thus it is fully adaptive. However, as the goal of VUSS is in opposite to the goal of ANC system, it is not possible for both the VUSS and ANC adaptive algorithms to operate “on-line”. Therefore VUSS usually adapts itself on the beginning of operation (after switching the system on), and then the adaptation of VUSS is turned off allowing the ANC system to operate properly.

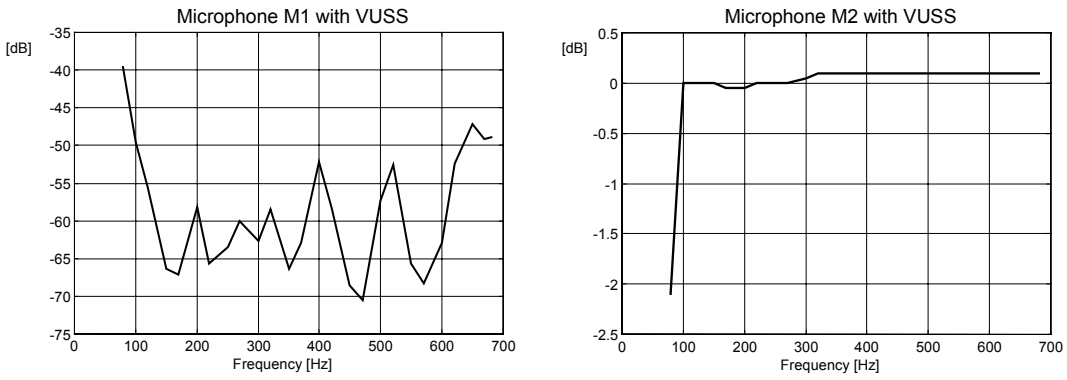


Fig. II.17. The performance of Virtual Unidirectional Source of Sound.

The virtual unidirectional source of sound proved to be very efficient. It attenuated the sound propagating upstream the duct on average level of 60 dB in frequency range between 100 and 600 Hz. On the other hand, the level of sound propagating downstream the duct was very effectively equalised over the same frequency range. The performance of VUSS for microphone M1 and M2 points is presented on Fig.II.17.

Research on active control of noise and vibration
3-D Zones of Quiet

J. Figwer, Z. Ogonowski, M. Michalczyk, K. Czyż

Creation of 3-D zoned of quiet is one of the most exiting and difficult control problems. They are needed in a number of areas e.g. in offices, cars, helicopters, aeroplanes etc., on industrial shop floors, in concert halls, audio recording studios etc.

The creation of 3-D zones of quiet is investigated in the Active Noise Control Laboratory. The basic problems solved in the laboratory is developing and verifying control structures and algorithms for spatial noise attenuation. The laboratory is equipped with a number of loud-speakers, measuring microphones, amplifiers, antialiasing and forming filters, computers with digital signal processing cards, additional measuring and testing units. The microphones and loud-speakers are placed in a specially designed enclosure (Fig.II.18). Noise is entered by a primary source of sound (speakers activated with the sound generators).

The zone of quiet is created in the enclosure by using a secondary source of sound (speakers controlled by a computer). Control algorithms are implemented in DSP cards fit into PC computer providing a shell of the control system. Thus requirement concerning fast sampling in active noise control is assured. DSP allows also implementation and running in the real time complex identification procedures.

Fig. II.18. Control equipment in 3-D Zone of Quiet Laboratory.

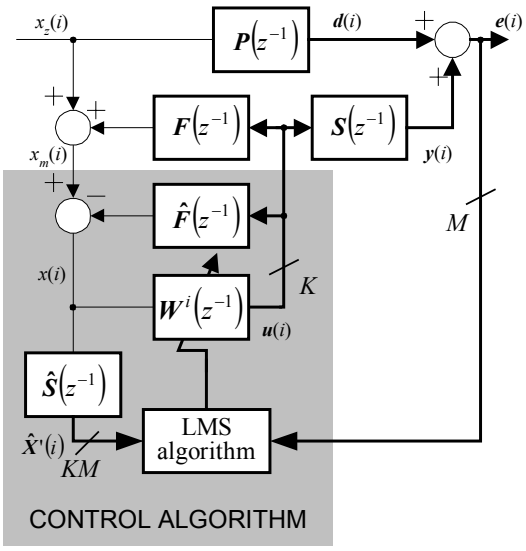


Fig. II.19. Block diagram of the three-channel ANC system.

Adaptive control is then possible. Number of modern control algorithms are investigated in the laboratory e.g. minimum-variance control, zero and poles placement approach, adaptive feed-forward filters, adaptation in the frequency domain, phase-shift algorithms etc. The exemplary structure of the ANC system used for creation of 3-D zones of quiet is shown in Fig.II.20. Libraries of specialised software are developed. They contain procedures for identification, control, signal processing, data visualisation, signal generation and analysing. All the software allows to design, test and validate the control algorithms and structures. An example of 3-D zone of quiet created in the laboratory using three-channel ANC system is shown in Fig.II.20, the corresponding time curve of the error signal is shown in Fig. II.21.

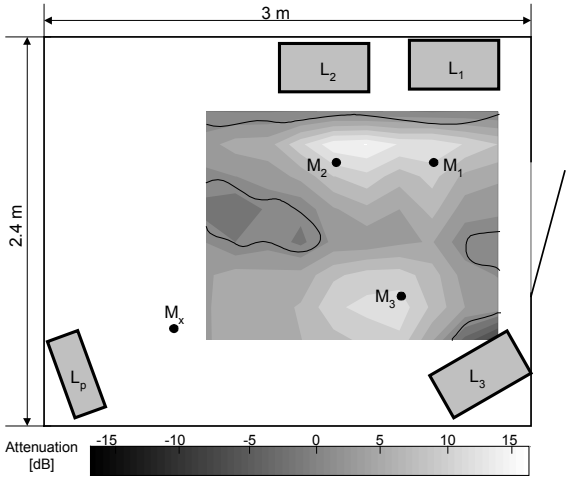


Fig. II.20. 3-D Zone of Quiet created for the broadband random noise.

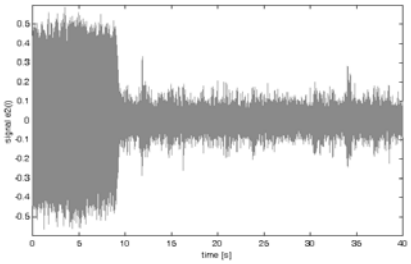


Fig. II.21. Time curve of error signal during attenuation the broadband random noise.

Research on active control of noise and vibration
Active vibration control

Z. Ogonowski, K.Plaza

Active and semiactive vibration control became one of the most exciting research topics of the control area in the last few years. The research conducted by Industrial Control Group focused on fully active suspension systems. Magnetic model of this suspension with rotation possibility (so called magnetic bearings) is used. Technology in this field has been developed very intensively in the last decade.

The most impressing application seems to be the Japanese superconducting magnetically levitated train proposed for the new Chuo Shinkansen link between Tokyo and Osaka. There are many specialised technological solutions for magnetic levitation, however, development in technology does not go towards the improvement of the control quality. The magnetic suspension represents difficult to control plant due to an open-loop instability, non-linearity and nonstationarity.

A sophisticated (intelligent) control is then necessary to be applied to provide acceptable quality of control. Standard PID controllers provide stable control but the quality of transient responses is poor. The improvement has been done using specialised methods of control system design based on Weighted Minimum Variance and Adapted

WMV control. The AWMV controller has been used for extra controller tuning for 4 independent axis.

Fig. II.22. Magnetic bearing system MBC 500.

In the rotary machines a problem of oscillatory disturbances arises. Stabilisation problem is usually solved using modal methods. Modal controller can attenuate the disturbances if poles of the closed loop system are located to provide small frequency of the natural oscillations. The demand is used in other approaches, however, none of the controllers can eliminate oscillatory disturbances completely. The research in ICG has been directed to improve the rate of attenuation.

Two approaches have been developed: with direct disturbances measurement and with estimation of the rotational speed. The control system consists of a fixed controller and adaptive compensator. The compensator is a phase shifter of the proper order. Its parameters are unknown and non-linear function of the rotary speed. Two structures of the adaptive algorithm are proposed: gain scheduling and parametric adaptation. A hybrid algorithm was also investigated. The algorithms have been tested using model of magnetic bearings (MBC 500 of Magnetic Moments – see Fig.II.22) extended with pneumatic system of rotary speed measurement and control.

More accurate discrete, nonlinear, MIMO models of the MBC500 were investigated throughout the identification with the use of gradient descent methods.

Research on microprocessor instrumentation
Development of ultrasound detectors
Ultrasonic system for measurement of liquid surfaces

D. Bismor, M. Pawełczyk

In industry, there is a huge demand for devices capable of distance measurement in liquid environments. An exemplary application of such devices is oil distillery, where subsequent layers, like solvent, emulsions, brine and sludge (see Fig.II.23) are separated

in large tanks. Therefore, the development on the ultrasonic measurement device based on Hitashi microprocessor and advanced signal processing is one of the main aims of the authors with cooperation with Uniprod Company.

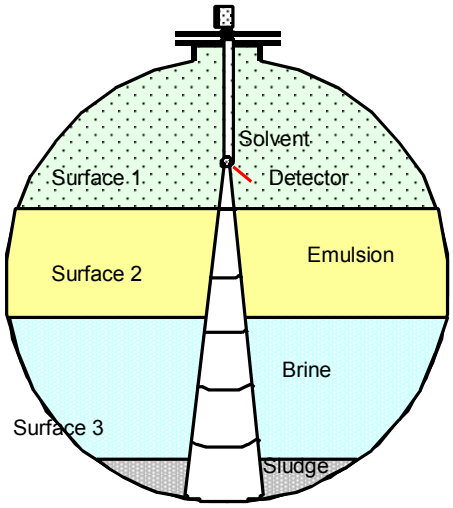


Fig. II 23. Layer detection in oil destilery tank.

The hardware created for the purpose of ultrasonic detector has modular structure and consists of analog part, digital part and interfaces allowing operation with or without supervisory computer. The transducer and hardware has been presented on Fig.II.24 and Fig. II.25.

Fig. II.24. Transducer head.

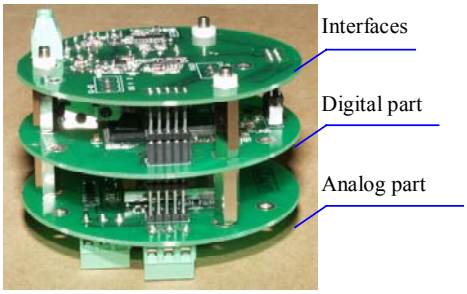


Fig. II.25. System boards.

The digital part of the system aims at supervising analog part of the device, i.e., ultrasonic signal generation, trigerring of aquisition procedure, etc. Additionally, in each cycle, digital signal processing algorithm IDEAL-F® (Intelligent Distance Exploring Algorithm for Fluids) is run. The algorithm has been developed by the authors based on advanced digital processing added by the physical system knowledge as well as by heuristics.

The algorithm performs the following operations: preliminary processing, echo quality evaluation, signal differentiation, peaks detection, unwanted peaks rejection, and finally correct distance calculation. Optionally, the algorithm designed allows tracking changes of up to two layer widths and recognition of permanent obstacles. What is more the algorithm detects liquid disturbances like mixing, air bubbles, etc. The exemplary signal acquired with presented system has been shown on Fig.II.26.

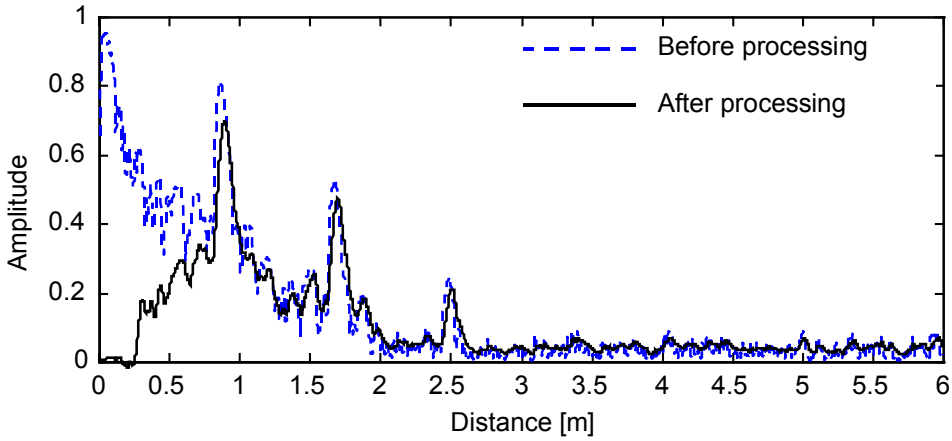


Fig.II.26. The exemplary signal prior to and after preliminary processing.

Research on microprocessor instrumentation
Adaptive ultrasonic system for distance measurements in the air under presence of obstacles using intelligent distance exploring algorithm ideal®

M. Pawełczyk, D. Bismor

Ultrasonic distance, level and flow measurements gain significant interest in recent years as they are non-invasive and easy to perform. They are often met in sophisticated industrial plants as well as in many domestic appliances. A well recognised example is an ultrasonic distance detector supporting car parking.

In the work reported an advanced adaptive algorithm IDEAL® (Intelligent Distance Exploring Algorithm) has been designed that allows measurement of distance, level and flow with high accuracy under the presence of various obstacles in the acoustic field. Contrary to other similar systems available on the market the one proposed identifies automatically the obstacles and harmonic reflections, providing fast measurement with high precision. The electronic hardware, based on a Hitashi processor, has been developed by UNIPROD Sp. z o.o. It aims at supervising the analogue part of the device, i.e., ultrasonic signal generation, triggering of acquisition procedure, etc.

Additionally, in each cycle, IDEAL® algorithm is run. The algorithm performs the following operations: preliminary processing, echo quality evaluation, signal differentiation, peaks detection, unwanted peaks rejection, obstacles recognition, and finally multi-criteria result analysis.

The algorithm also contains adaptive procedures accommodating the processing to changes in environmental conditions (presence of a pipe, grate, fan, stirrer, temperature variations). Additionally, it allows automatic tuning to various transducers.

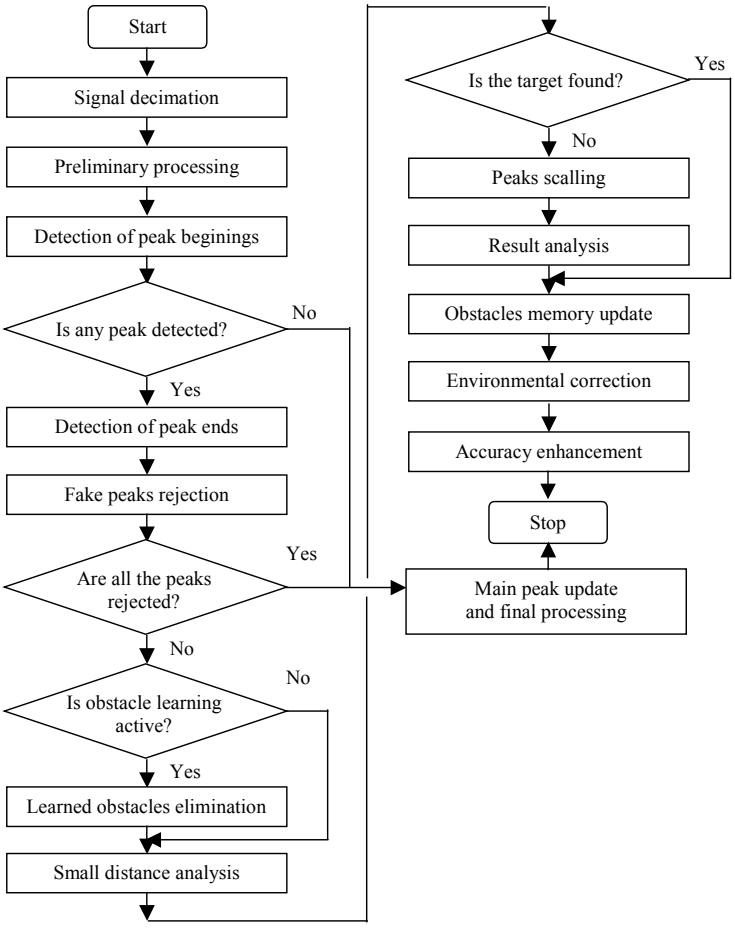


Fig.II.27. Flow diagram of IDEAL®.

Graphical interface of IDEAL® and the exemplary applications where the algorithm has been found useful are presented in the figures below:

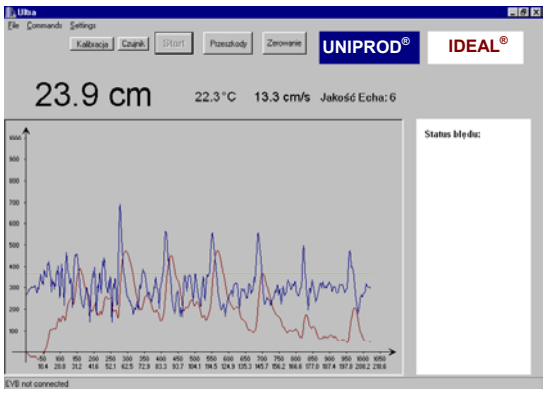


Fig.II.28. Graphical user interface.

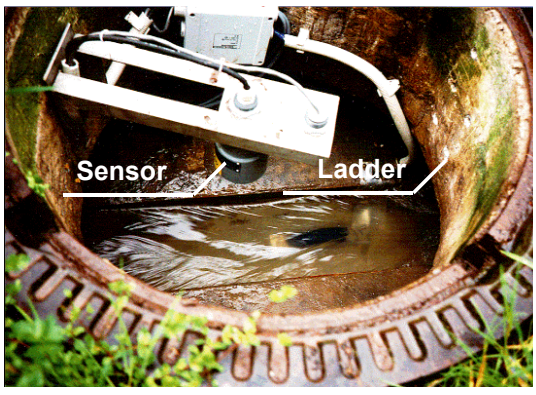


Fig.II.29. Flow and level measurement in a sewage system.

Fig. II.30. Fill-in measurement in storage bins.

Fig. II.31. Level measurement in sewage-treatment plant.

Research on eye movement signal processing

J. Loska, J. Hajda

The OBER2 measuring system has already been honored on the 5th European Forum of Competitive Technology TEC'96 in Grenoble and on the TECHNOMART'97 in Osaka. This system also got the award of Ministry of Education. Research on eye movement signal processing is directed towards medical and technical applications of the eye movement measuring system OBER2.. Another stream of activities is concerned with developing hardware and software of the measuring system. A team headed by Professor J. Ober has designed the system.

Infrared systems, which flash the infrared light into eyes during a very short period of time are one of the safest systems for eye movement measurements. Such a system is the OBER2.

This system is an advanced analog-digital device, which works with IBM PC compatible computers and communicates with these by serial port connection.

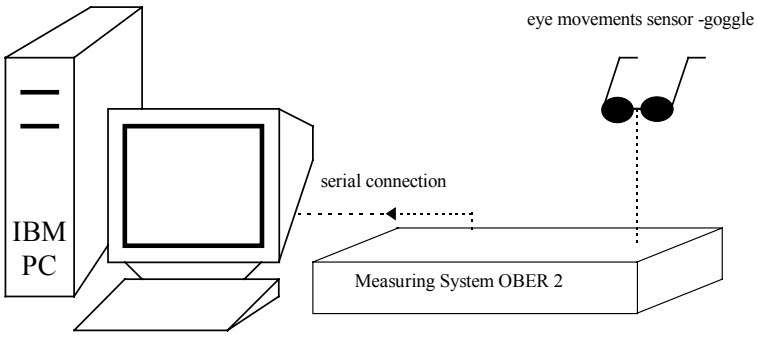


Fig. II.32. The view of measuring stands.

The bases of all infrared light eye movement measuring systems are the same: the infrared beam is being send in the direction of eye by infrared transmitters positioned close to the eye. The light reflected by eye is collected by the system of receivers. This method works due to the different reflective properties of the iris compared with the

sclera (the white of the eye). When the eye moves to one side, less infrared light is reflected back to the detector on one side of the eye then the other.

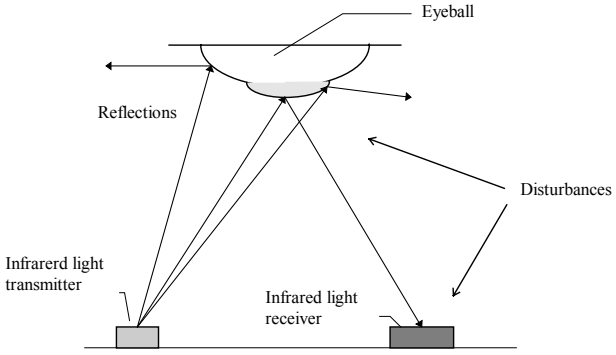


Fig. II.33. The principle of measurement.

Using the OBER2 system, the eye movement of both eyes is measured in horizontal and vertical axes. This operation can be done two thousand times per second. All of those systems have problems with disturbances that are caused by changing in an outside ambient light. That is why the system includes background suppression mechanism attenuating outside ambient light with factor about 40 dB for frequency up to 100 Hz. One of conducted research topic is falling asleep detection, which can be applied to warn drivers before falling asleep while long-time driving. Although the relation between eye movement abnormalities and children dyslexia is not clear, patients with certain types of acquired ocular motor abnormalities do have difficulties with reading. On the other hand, many of the optic system disorders is possible to detect using the OBER2 system. That is why one of the research topic is detection of children dyslexia. Most of practical applications of the eye movement measuring systems need to concentrate on the special elements of eye movement or on the most essential types of movements. One of the most frequently mentioned types of movements in medical applications are saccades and fixation.

The analysis of eye movement signals and selection the most essential types and elements of eye movement needs to use many special methods:

- Digital signal processing,
- Time-series analysis,
- Wavelet analysis,
- Neural networks,
- Numerical methods.

Fig. II.34. Testing the driver with OBER2.

An important task connected with studies on performance of Ober2 system is improvement of quality of signals obtained with this device. As far as attenuation of influence of electromagnetic and ambient light disturbances is concerned several methods of digital filtration are analysed. Research was also conducted on algorithm for attenuation of influence of blinks on useful signal.

During the last two years a major reconstruction of the Ober2 hardware has been accomplished. As a result the data transfer between the transmitters and processor as well as the processing capabilities have been improved considerably.

Research on Controllability of Dynamical Systems

J. Klamka

Stability, controllability and observability are one of the fundamental concepts in modern mathematical control theory. They are qualitative properties of control systems and are of particular importance in control theory. Systematic study of controllability and observability was started at the beginning of sixties, when the theory of controllability and observability based on the description in the form of state space for both time-invariant and time-varying linear control systems was worked out.

The concept of stability is extremely important, because almost every workable control system is designed to be stable. If a control system is not stable, it is usually of no use in practice. Many dynamical systems are such that the control does not affect the complete state of the dynamical system but only a part of it.

On the other hand, very often in real industrial processes it is possible to observe only a certain part of the complete state of the dynamical system. Therefore, it is very important to determine whether or not control and observation of the complete state of the dynamical system are possible. Roughly speaking, controllability generally means, that it is possible to steer dynamical system from an arbitrary initial state to an arbitrary final state using the set of admissible controls.

On the other hand observability means, that it is possible to recover uniquely the initial state of the dynamical system from a knowledge of the input and output. Stability controllability and observability play an essential role in the development of the modern mathematical control theory.

There are important relationships between controllability, observability and stabilizability of linear control systems. Controllability and observability are also strongly connected with the theory of minimal realisation of linear time-invariant control systems. Moreover, it should be pointed out that there exists a formal duality between the concepts of controllability and observability.

In recent decades modern control theory of linear dynamical systems has been the subject of considerable interest of many research scientists. It has been motivated, on the one hand, by the wide range of applications of linear models in various areas of science and engineering and, on the other hand, by the difficult and stimulating theoretical problems posed by such systems.

In the literature there are many different definitions of stability, controllability and observability which depend on the type of dynamical control system. The main purpose of this article is to present a compact review over the existing stability, controllability and observability results mainly for linear continuous-time and time-invariant control systems. It should be pointed out that for linear control systems stability, controllability and observability conditions have pure algebraic forms and are rather easily computable. These conditions require verification location of the roots of a characteristic polynomial and of the rank conditions for suitable defined constant controllability and observability matrices.

The main purpose of the research program is:

- to give a compact review over the existing controllability and observability results for different types of finite-dimensional and infinite-dimensional continuous and discrete control systems,

- to present new results concerning controllability and observability of discrete both linear and nonlinear control systems with many independent variables,
- to give sufficient conditions for constrained approximate controllability of semilinear infinite-dimensional control systems,
- using the results taken from the theory of linear unbounded operators and semigroups of linear operators to formulate necessary and sufficient conditions for different kinds of controllability for linear continuous-time infinite-dimensional systems,
- to discuss as illustrative examples approximate controllability problems both for linear and semilinear distributed parameter systems with constrained controls, defined in constrained domains,
- to solve effectively approximate controllability problems for distributed parameter control systems defined in infinite-domain.

Research on distance learning

J. Mościński

Dr J. Mościński has participated in the ODL (Open and Distance Learning) component of the SOCRATES programme, within the LINK project: „LINK – Linking professors for producing better courses". The global objective of the project focused on decreasing the workload concerning the preparation of multimedia oriented lectures and courses. The lecturers taking part in the project collaborate with their colleagues from other universities towards developing and enhancing multimedia courses from engineering education domain. The lecturers also spread around the information concerning the enhanced multimedia courses by means of computer network. The methodology of creating, implementing and running the multimedia and remote courses has been also covered by the LINK project activities. The partners worked towards "producing" the courses in a semi-automatic manner, the systems of Internet/Intranet based course development and running have been also developed, including the Internet database oriented systems. The LINK project was part of the e-learning development strategy at the Institute of Automation. Dr J.Mościński role in the project was local co-ordinator and contact person on behalf of Silesian University of Technology, Gliwice, as well as courses developer. Other partners: Karel de Grote Hogeschool, Antwerp, Belgium; Instituto Superior Tecnico Lisboa, Lisbon, Portugal; Instituto Politecnico do Porto, Porto, Portugal; University of Northumbria, Newcastle, England; Studio TEOS s.r.l., Milan, Italy; Politechnika Łódzka filia Bielsko Biała, Poland.

Dr J.Mościński is participating in the SOCRATES-MINERVA remote education project entitled „LABLINK. Virtual student exchange by linking laboratories". The main objective of the project is to develop the methodology and organization of remote laboratory experiments for engineering education. The project is innovative in both technical and pedagogical sense, parts of the projects concern also the methodology of teaching, learning and grading. The testing group in the project will consist of engineering students from partner universities, especially from mechanical engineering, electrical engineering and automation and robotics fields. In the dissemination phase of the project the developed virtual and tele-laboratories will be used in other types of education – like evening classes, doctoral studies, life-long learning and industry oriented courses. Dr J.Mościński, Dr h. J.Figwer, Dr Z.Ogonowski and Mr K.Czyż are involved in the preparation of virtual and tele-laboratories in the field of active noise

and vibration control as well as adaptive control. Dr J.Mościński role in the project was local co-ordinator and contact person on behalf of Silesian University of Technology, Gliwice, as well as courses developer. Other partners: Karel de Groote Hogeschool, Antwerp, Belgium; University of Strathclyde, Glasgow, U.K.; CVUT Praha, Prague, Czech Republic; FH Aalen, Aalen, Germany; Kauno Kolegija, Kaunas, Lithuania; Haute Ecole Paul Henri Spaak, Brussels, Belgium; Katholieke Hogeschool Sint-Lieven Gent, Gent, Belgium, Rousse University "Angel Kanchev", Rousse, Bulgary.

Dr J.Mościński is participating in the SOCRATES Thematic Network project entitled „THEIERE. Thematic Harmonisation in Electrical and Information Engineering in Europe". The main objective of the project include the review of curricula concerning Automation and Robotics, Electronics and Telecommunication as well as Informatics fields. The tasks of adjusting and further collaborative development of parts of curricula are also covered in the project. The partners work also on the development of tools and procedures concerning the exchange of students between universities from European countries as well as on transferring the experience and achievements concerning such exchange. Dr J.Mościński role in the project was local co-ordinator and contact person on behalf of Silesian University of Technology, Gliwice, as well as courses developer. Other partners: around 80 universities from several European countries.

The THEIERE network project has been finished in 2004 and special THEIERE-DISS project has been proposed and accepted as one year extension of the network project oriented towards the dissemination of results and achievements worked out as a result of THEIERE network based collaboration. One of the main outputs of the THEIERE network was the monograph "Towards the Harmonisation of Electrical and Information Engineering Education in Europe", which was elaborated during the academic years 2002 and 2003 as part of the THEIERE Thematic Network activities and is the basis of dissemination activities.

The EIE-Surveyor proposal concerning the network of more than 100 European universities working on the reference point in the field of Electrical and Information Engineering, has been prepared in 2004 and preliminarily accepted. Dr Mościński is one of the authors of the proposal and proposed local coordinator at Silesian University of Technology.

Dr J.Mościński is participating in the iNEER – International Network for Engineering Education and Research activities, as the iNEER network member. The main objective of iNEER is to help advance engineering education and research in regions around the world through international linkages and cooperative partnerships. It is an informal, networking community comprised of educators from academe, industry and government bonded by a desire to work collaboratively to elevate the quality of engineering education in institutions around the world. The ultimate goal is to enhance the learning process in particular and the education experience in general for students who will become engineers of the 21st century. One of the most important activities of iNEER is the annual organisation of international conference: ICEE – International Conference on Engineering Education. Dr J.Mościński has participated in the organisation of ICEE conferences in Manchester, 2002 as well as concerning the ICEE-2003 conference in Valencia and ICEE-2004 in Gainesville (USA), as the conference Steering Committee member and the originator and chairperson of special sessions concerning advances in engineering education with respect to web-based and distance learning solutions and control and identification courses. Dr Mościński has been also involved in starting new International Conference on Engineering Education and Research, iCEER. The first iCEER conference was held in Olomouc, Czech Republic, in 2004, and the second one was organized in Taipei and Tainan, Taiwan, in 2005. Dr

Mościński was involved in the preparation of these conferences as a member of International Steering Committee.

Remote Active Noise Control Laboratory

J. Figwer, K. Czyż

Rapid development and dynamic expansion of the Internet in the last decade has brought new information technology tools in education. Universities have tried to take advantage of the new information technology tools in course delivery methods. These tools have been adopted for enhancement of the educational experience of students contributing mainly to real-world validation of the theoretical foundations taught in lectures.

It opened new possibilities of organising laboratory sessions - virtual and remote laboratories accessible over the Internet have been developed. Unlike traditionally, their use does not require student's physical presence in the laboratory. Students may conduct laboratory experiments remotely using the Internet. The virtual laboratory concept allows students to access to hypothetical laboratory experiment setups that are simulated using computers. Students receive over the Internet only results of experiments. In this case, there is no need to purchase laboratory equipment used in the corresponding real-world laboratory setups. In contrast to virtual laboratories, remote laboratories allow students to see what is happening in real- world laboratory setups at remote Internet sites and sometimes to manipulate expensive laboratory equipment remotely.

In the last years under Socrates Minerva Project LabLink a pilot set of remote laboratories aiding education of undergraduate university students in mechanical and control engineering have been developed. One of these laboratories is an Active Noise Control (ANC) laboratory placed at the Institute of Automatic Control, Silesian University of Technology, Gliwice, Poland.

The remote ANC laboratory is equipped with a number of loud-speakers, microphones, amplifiers, antialiasing and forming filters, computers with digital signal processing cards, sound levels meters, signal analysers and signal generators (Fig.II.35). The microphones and loud-speakers are placed in a specially designed laboratory office room in which spatial zones of quiet are created.

a) b)

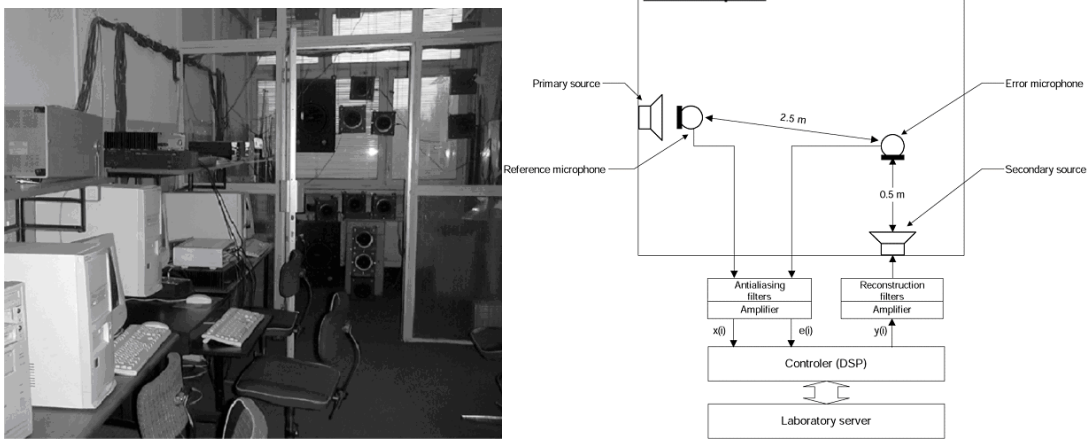


Fig. II. 35. ANC laboratory: a) control and laboratory office rooms; b) scheme of one channel ANC system.

Experiments in the ANC laboratory as well as the corresponding laboratory equipment may be remotely controlled over the Internet. The general concept of remote access to ANC laboratory and its remote control is based on client-sever architecture Fig.II.36.

The main goal of remote ANC laboratory is to share expensive ANC laboratory equipment among students and researchers. This equipment is accessible for remote users through the ANC laboratory server. Remote access of users to the ANC laboratory server is based on RealVNC (Virtual Network Computing) software.

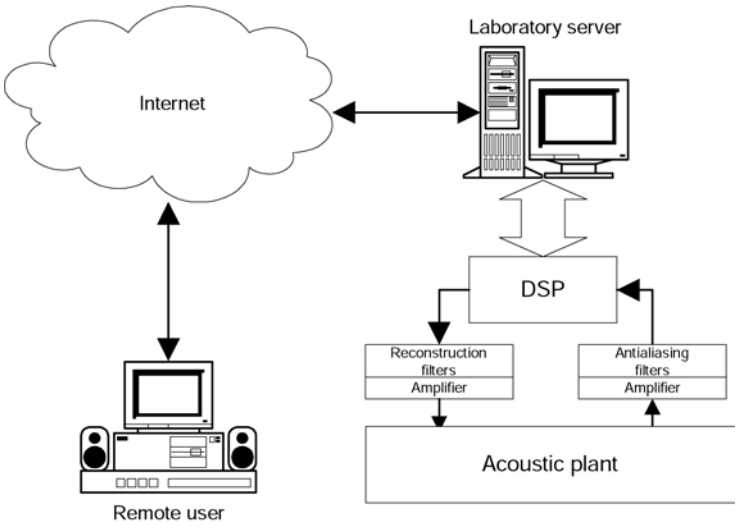


Fig. II.36. Remote access to ANC laboratory.

This software allows to observe laboratory server desktop and to interact with this desktop from remote workstation. Interaction with the desktop of ANC laboratory server may be realised from any workstation connected to the Internet. RealVNC is a hardware platform independent software. It is a kind of system service that sends frame-buffer and displays its contents in remote user Internet browser window. All operations performed with keyboard and mouse by remote user in active area of laboratory server desktop are transmitted over the Internet to ANC laboratory server. These operations are processed by the ANC laboratory server (every operation related with input/output actions is executed on the server), and only visible changes of desktop are transmitted back from the ANC laboratory sever to remote user workstation.

Access of remote users to ANC laboratory may be realised over the Internet by using any Internet browser with SUN Java installed. Laboratory Internet website contains a short course illustrating basic concepts of active noise control. The course consists of a set of laboratory instructions together with the corresponding software application ANC_Lab. This application simplifies interaction of remote ANC laboratory users with DSP board. Its interface allows remote users to design and perform laboratory identification and control experiments as well as to observe obtained results.

The remote Active Noise Control laboratory is reachable under **http://lablink.ia.polsl.gliwice.pl**.

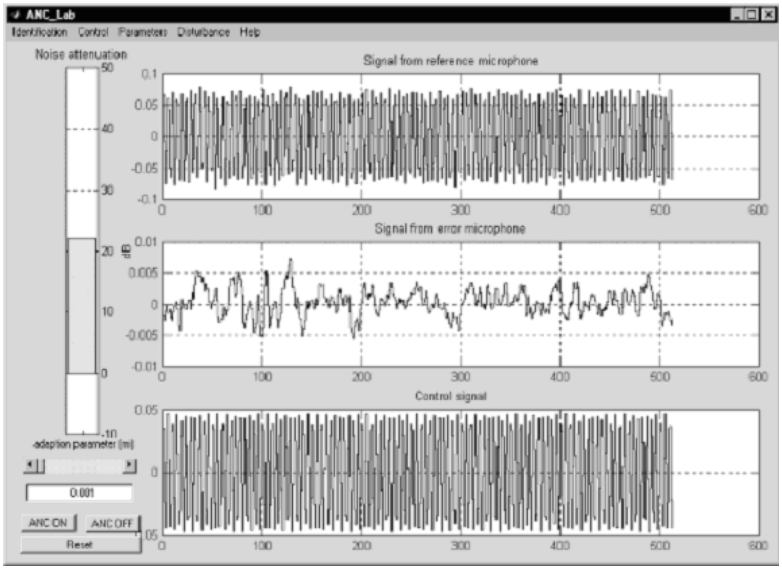


Fig. II.37. Main screen of ANC_Lab application.

Research on constraint logic programming

A. Niederliński, T. Szczygieł, W. Legierski

Constraint logic programming (CLP) may be defined as a body of techniques used for solving problems with constraints. The idea is: problems to be solved are modelled using elementary predicate logic, in a way that turns the model into a main part of the problem-solving program. Constraint Programming (CP) is an emerging software technology with a growing reputation for providing quick solutions to complicated (mainly combinatorial) problems of constraint satisfaction and optimisation, which form the heart of the majority of decision and control problems. What's more – if coupled with logic into Constraint Logic Programming (CLP) – it opens the doors to various paradises of declarative programming styles.

CLP languages work by tightly integrating traditional Logic Programming as given by Prolog, Constraint Satisfaction/Solving as developed in Artificial Intelligence and Optimisation as developed in Operation Research. The research is aiming at solving two difficult combinatorial problems: a university time-tabling problem and a two- and three dimensional angle placing problems. Solutions for both problems are developed using the CHIP v.5.3 constraint logic programming language and the Mozart programming language.

The attractiveness of using a CLP language is first and foremost the bridging of considerable semantic gaps existing between conventional (integer programming) formulation of the problems and the CLP formulation. Thanks to global constraints like cumulative(), diffn() and among(), a small number of CHIP code lines is usually enough to solve problems for which an integer programming formulation needs thousands of 0-1 variables and correspondingly huge matrices.

The price to be paid for these advantages is to learn a new way of formulating the problems, that makes them amenable to CHIP mechanisms. The great engineering advantage of using CLP tools is that the engineer is always in touch with his/her problems and does not have to worry about the nuts and bolts of the solution. The

advances made in mastering and applying CHIP have been instrumental in introducing constraint logic programming into the M. Sc. curriculum.

CLP research has been done on the following topics:

1) Solving selected packing problems (Tomasz Szczygieł)

The main goal of this research was to prove that Constraint Logic Programming may be used as a powerful tool to solve many different and difficult packing problems on the plane and in the space. To attain this goal the following methods have been compared:

- Integer Linear Programming as a traditional approach to packing problems. It has been demonstrated that the method requires a prohibitively large number of variables and correspondingly large dimensions of matrix A. Formulating a packing problem in terms of ILP is often logistically impossible. Besides the ILP approach suffers from a semantic gap, that is the gap between the original problem formulation and the canonical target formulation needed for the application of the ILP methods,
- Dynamic Programming is another traditional approach to packing problems. The DP approach suffers from another form of semantic gap: the packing problems need to be a formulated as a multistage decision process. To optimize this process, a large number of its sub processes have to be optimized first. This contributes adversely to the numerical efficiency of the optimization,
- Constraint Logic Programming is a new approach to packing problems. It is declarative and therefore there is no semantic gap between the original problem formulation and the program that solves it,
- For all the packing problems considered the number of variables in the final source program is the smallest in the CLP programs. The difference may be so great that even writing down a correct model may be a very difficult task,
- Modifying the problem input data for the ILP method (no matter what the sizes and number of small figures are) can only be done by reformulating all the equations for the ILP model,
- Modifying the problem input data for the DP method can only be done by generating new constraint propagation formulae and new DP recursion formulae,
- That means that for both the ILP and DP methods any change of input data compels us to develop the model from the scratch: nothing that has been done before is of any use,
- Moreover, increasing the number of small figures for the DP method increases the number of points to be considered at each stage exponentially,
- This is strongly contrasted with the CLP method: there is no need to change the CLP model when its input data is changed. More importantly, no previously used predicates need to be changed for the new input data,
- Additionally the times needed to obtain solutions for the ILP and DP methods are generally much larger than the CLP method. For large problems the difference is even more pronounced,
- All the CLP examples presented were for placing a relatively small number of elements. This does not adverse affect the generality of the programs. In order to increase the number of elements placed, it is only necessary to increase the number of elements in some lists. Of course, programs with an

increased number of elements will run longer and because of the inherent combinatorial explosion plaguing the placement problem, we might eventually have to be satisfied with a feasible suboptimum solution. The important thing is that those feasible suboptimum solutions are produced by the very same programs used to seek the optimum solution,

- In summary, for all the packing problems considered, CLP is the undisputed winner over DP and ILP, both in terms of simplicity of problem formulation, in terms of problem modification, in terms of program readability and finally in terms of computational efficiency.

2) Solving university timetabling problems (Wojciech Legierski)

Research in area of Constraint Programming and timetabling provided the following results: the ability to express complex constraints in a simple, declarative way is crucial for introducing the requirements of into the program and is decisive for their successful solution, custom tailored distribution (labeling) strategy is able to introduce 'soft' constraints during search, leading quickly to a 'good' timetable, incorporation of local search into constraint programming gives the ability to optimize effectively the timetable. User interface based on Visual Basic for Application and MS Excel gives ability for managing timetable data and printing results of the solution.

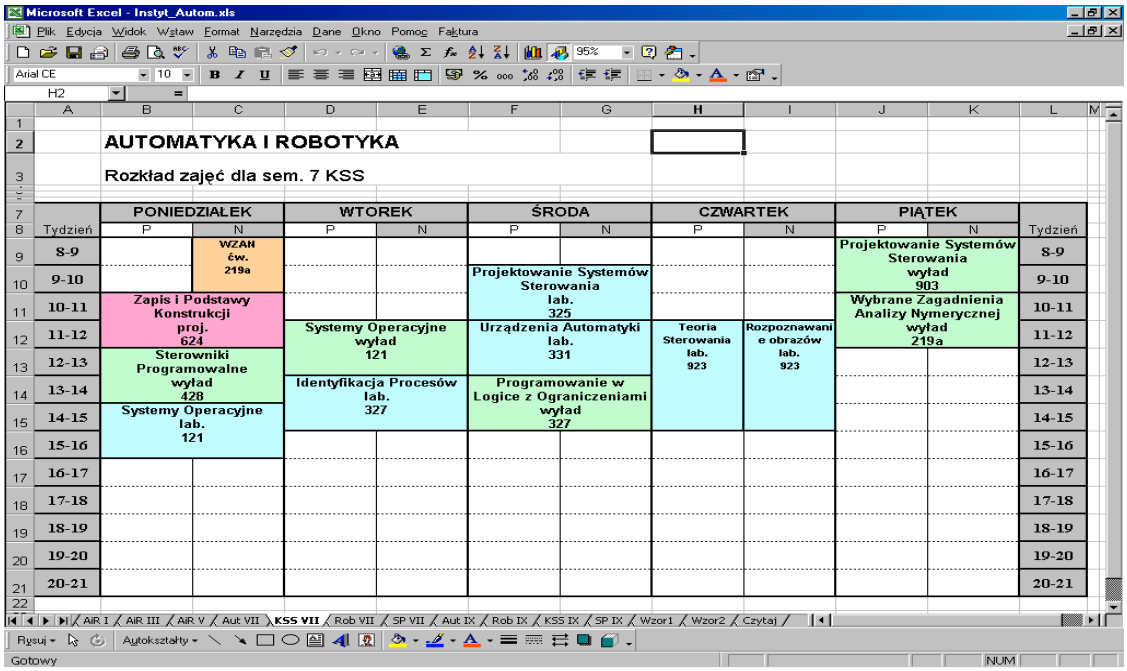


Fig. II.38. An Excel view of time-table generated by constraint programming.

Research on data mining for fraud detection

M. K. Szczepański

Fraud detection based on data collected in databases is one of many applications of knowledge discovery in databases. It is usually concerned with finding data objects that do not fit the general behaviour or model of the data, called outlayers. They can be found by looking for objects that are a substantial distance away from any of the

clusters in the data or show large differences from the average characteristics of objects in a group. Final result of such fraud detection doesn't have to be finding frauds (or abuses). It can be defined as narrowing set of suspects to a maximum.

Generally committing a fraud causes following results in database:

- appearance of a specific value of one (at least) of database table attributes,
- appearance of a specific relation between few database table attributes.

Many of fraud detection methods are based on looking for such results of frauds. Some methods use thresholds, which separate normal values of each database attribute from "fraudulent" values of these attributes. Other methods use rules that find specific "fraudulent" relations between attributes. But sometimes values of database attributes can be disturbed. If values of disturbances are equal or larger than changes of attributes values due to committing frauds, specific values and specific relations mentioned above are impossible to find. How such disturbances can arise? Their arising can be result of inaccuracy of measurements of values written down into database or influence of not measured variables (on database values). Research is just concerned with fraud detection based on data that contain such disturbances.

Research on expert systems

A. Niederliński

Expert system are decision-supporting software which consists of (more or less) universal reasoning systems and knowledge bases containing the entire problem-relevant knowledge. Because knowledge bases are text files, expert system solutions to decision problems are particularly friendly as far as their modification and development is concerned. The research aims at developing a range of rule- and model-based expert system shells (RMSE) covering a broad spectrum of modelling constraints: shells for elementary exact and uncertain reasoning (no rules with negated nonaskeable conditions are allowed) and shells for extended exact and uncertain reasoning (rules with negated nonaskeable conditions are allowed). The systems may be used to reason with (correspondingly) exact or uncertain knowledge bases , which consist of a rule base, a model base (arithmetical and relational models), a constraint base and an advise base with advice files. Practically unlimited nesting of rules and nesting of rules with relational models is allowed. The expert system shells are equipped with diagnostic facilities automatically checking rule bases, model bases, rule and model bases and rule and constraint bases for inconsistencies and redundancies and providing warnings and detailed diagnostic messages. Reasoning reports and final summaries may be generated upon request. All expert system shells have been implemented in Prolog (Visual Prolog 5.2). Both Polish and English versions of the shells are available on the website http://www.ekspert.wsi.edu.pl/

Both the elementary exact and elementary uncertain expert system shells have been successfully tested for a real-world application concerned with validating credit applications from small businessmen. This has been done as part of the Ph.D requirements by Tomasz Żurek in his thesis "Computer supported credit validation" (Gliwice, 2004).

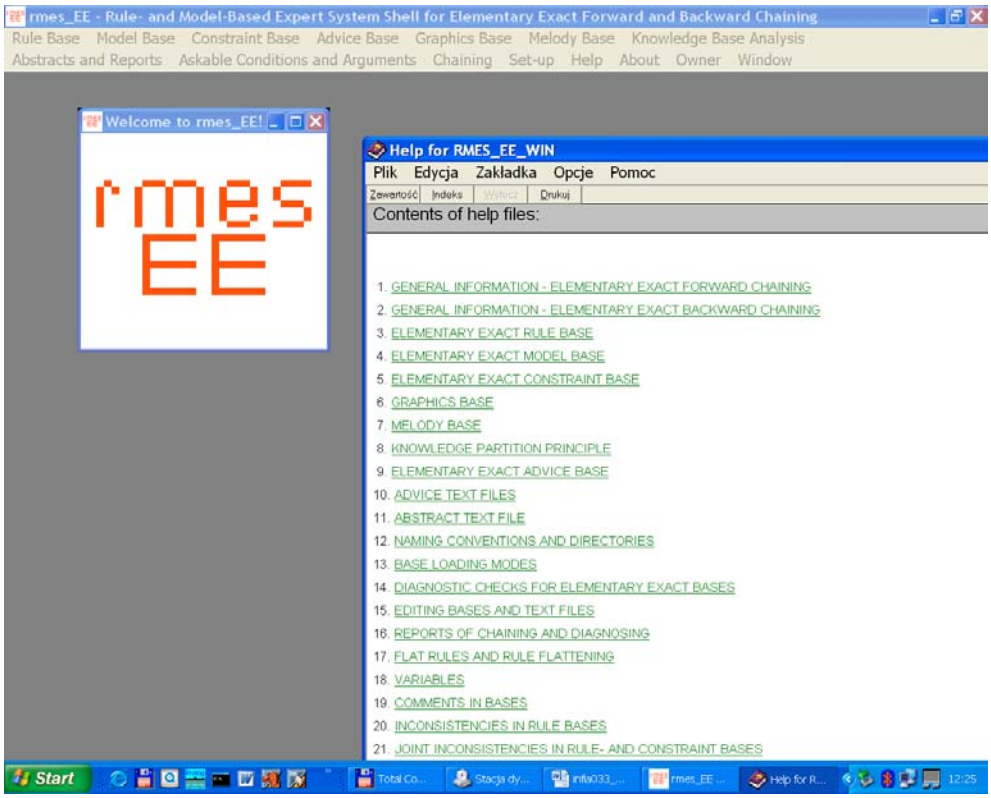


Fig. II.39. The user main interface for rule-and model based elementary exact expert system shells for Windows.

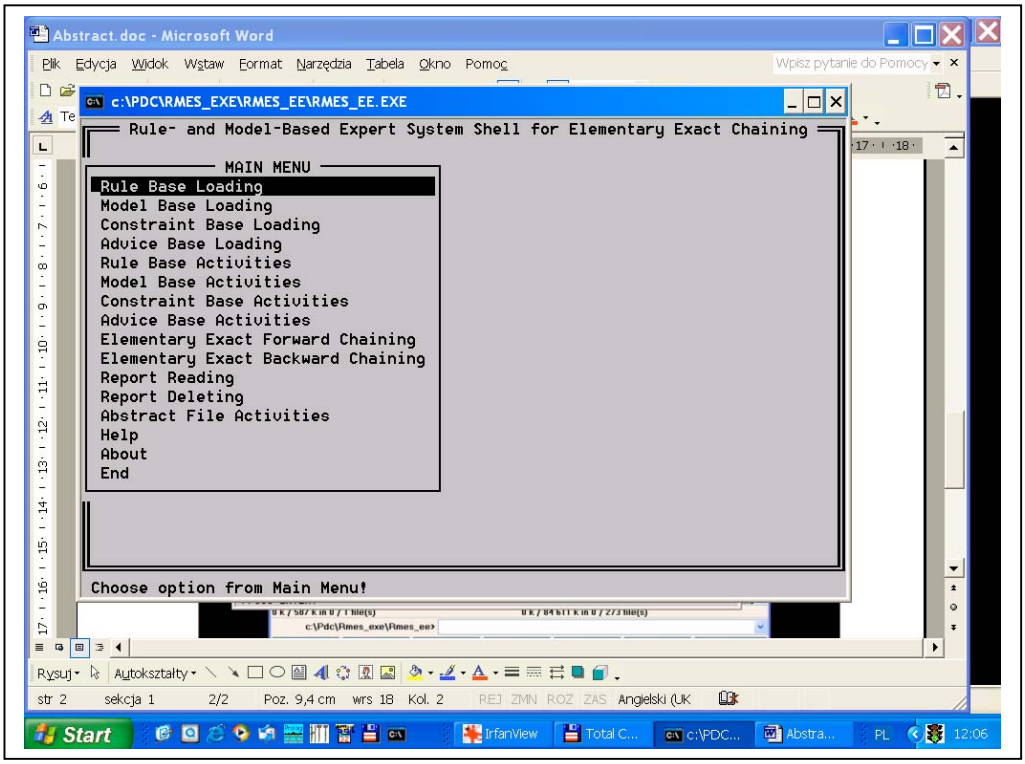


Fig. II.40. The user main interface for rule-and model based elementary exact expert system shells for DOS.

Workshop on Constraint Programming for Decision and Control

A. Niederliński, J. Figwer

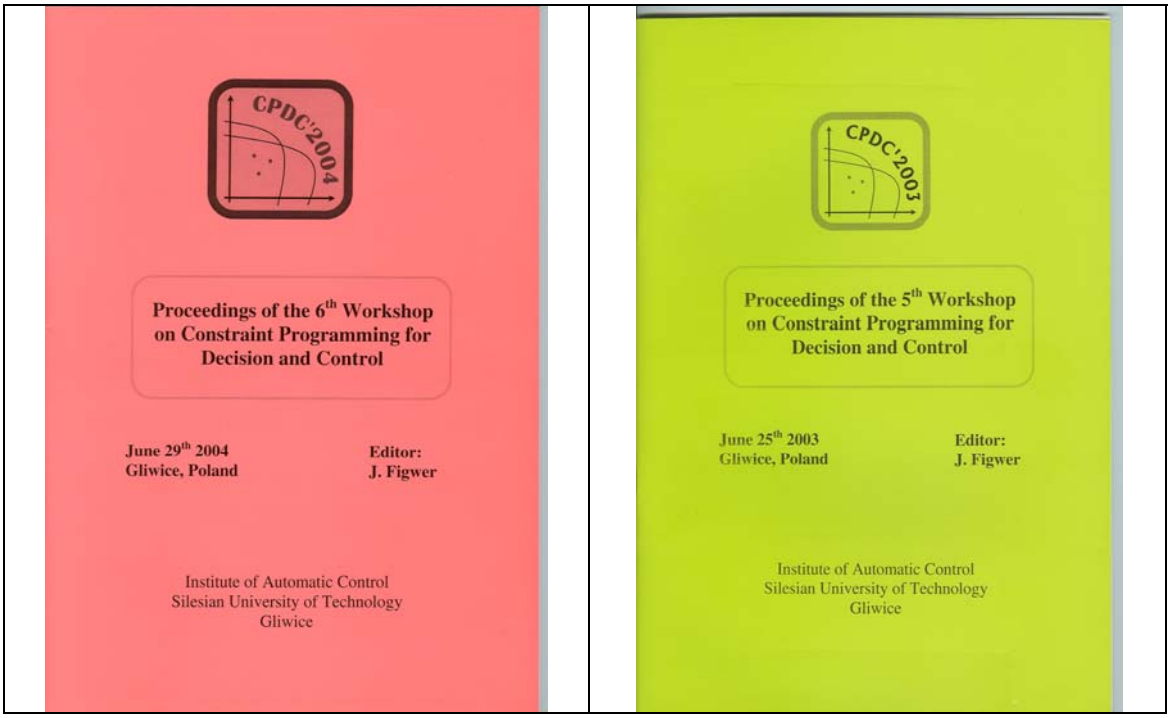
Professor Niederliński is acting as Chairman of Scientific Committee and Dr. Figwer as Chairman of the Organising Committee of the Workshop on Constraint Programming for Decision and Control. The 5-th and 6-th Workshops (CPDC'2003 and CPDC'2004) were organised by the Computer Control Group and took place at Gliwice in 2003 and 2004. The homepage of the Workshop is http://lemon.ia.polsl.gliwice.pl/cpdc2002.

The CPDC Workshops are an attempt to bring together people from Polish Universities interested in using CP or CLP for decision or control problem solving. To provide a better perspective on what others are doing, avoid being hampered by language barriers and create for all participants the opportunity to merge into the large international CP/CLP community, the Workshop was envisaged to be run in English. It addressed first of all the needs of graduate students working on theses using CP or CLP tools.

Papers presented during the CPDC'2003 and CPDC'2004 Workshops were devoted to:

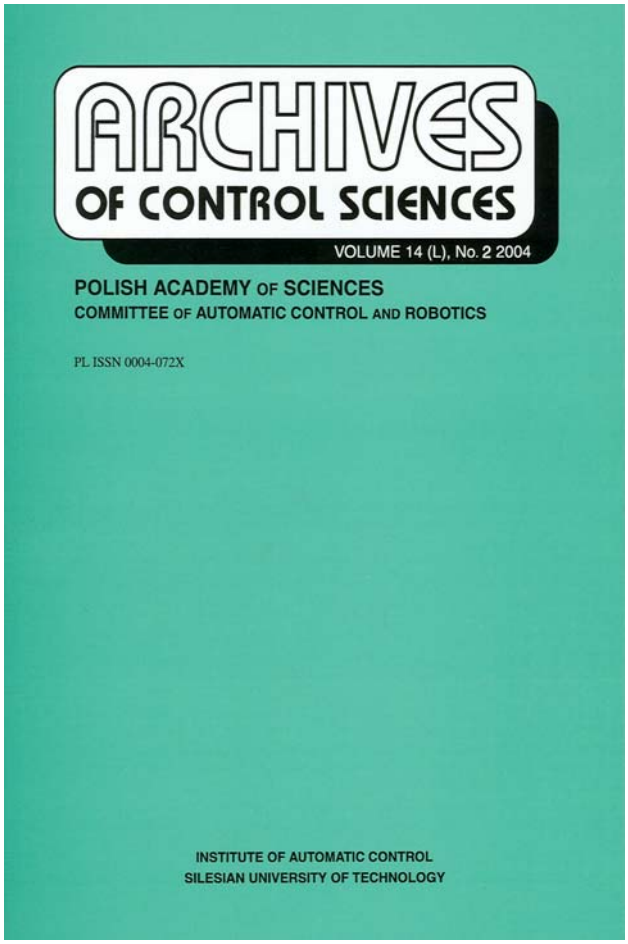
- Combinatorial decision and control problems like time-tabling, scheduling and resource allocation,
- Combinatorial and mixed optimisation problems,
- Comparative analysis of CP tools performance,
- Case studies of large-scale constraint programming applications,
- Teaching of constraint programming,

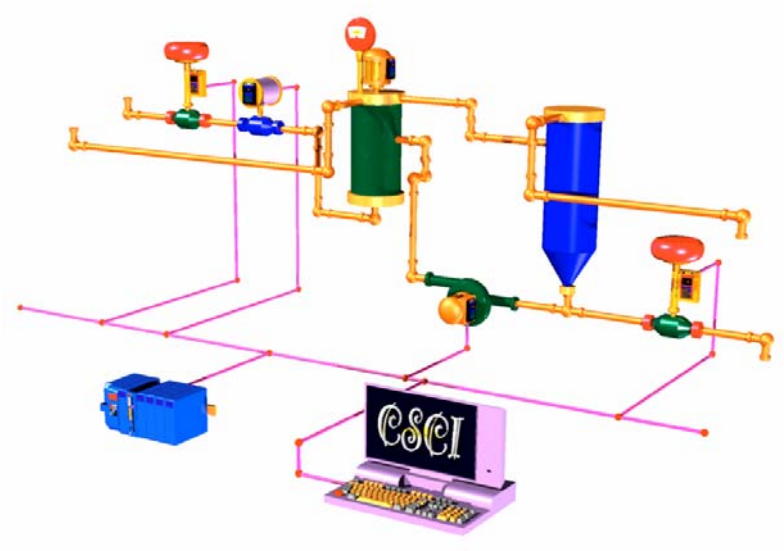
The Proceedings of both Workshops have been published, see below.



Editing the Archives of Control Sciences quarterly

Prof. A. Niederliński is is the Editor in Chief of Archives of Control Sciences (a quarterly of The Polish Academy of Science – committee of Automatic Control and Robotics). Dr Z. Ogonowski is Assistant Editor of the quarterly. There was 7 issues published in 2001and 2002 year including special issues devoted to: "Modelling and Control in Environmental and Food Biotechnology", "Recent Developments in Robotics" and "Granular Computing". Total 56 papers has been published in the last 7 issues with 29 papers from abroad. See the ACS homepage http://ia.polsl.gliwice.pl/acs for details e.g. abstract of the papers.





CONTROL SYSTEMS AND CONTROL INSTRUMENTATION GROUP

GENERAL INFORMATIONS

The most important areas of research interests in the group are as follows:

- Modelling, simulation and control of continuous industrial processes,
- Theory and practice of modelling and simulation,
- Real-time simulation and training systems,
- Modelling, simulation and control of biotechnological processes in the environment protection - aspects: activated sludge processes, sequencing batch reactors, biofilm processes, biofilters,
- Modelling, simulation and control of biotechnological fermentation processes - aspects: anaerobic processes, yeast fermentation, enzymatic processes,
- Intelligent equipment for automation: transmitters , actuators, regulators and controllers,
- Distributed control systems – industrial networks, agent-based control, holonic systems,
- Programming of digital regulators, controllers, monitoring and SCADA systems,
- Low-cost PC-based control systems,
- Development and design of control systems in chemical, power and environmental protection industry,
- TCP/IP-based virtual plants, controllers and control systems, OPC.

The CSCI group consists of eleven researchers (including two titular professors). The members of the group teach about twenty courses to about four hundred fifty students in two faculties: the faculty of Automatic Control, Electronics and Computer Science and the faculty of Chemical Engineering. The courses cover both traditional topics of modelling, simulation, control and programming, and more recent topics in the real-time distributed systems and intelligent instrumentation for automation fields.

Members of the Control Systems and Control Instrumentation Group were involved in the project entitled "Practical realisation of advanced control in distributed control systems of real-world processes" supported by National Committee of Scientific Research (KBN) under Grant No 4 T11A 019 24 (2003-2006).

Moreover together with System Engineering Group two important educational enterprises are undertaken. The first one started in the fall 2003 initiated new courses in Information Processing and Control in Biotechnology for students in Automatic Control and Robotics. The second one are interdepartmental studies in Biotechnology initiated by three Faculties. Our Faculty is responsible for specialization Bioinformatics and the study will start in the fall 2005.

RESEARCH ACTIVITY

Although the members of the CSCI group present some theoretical research results in the international publications (see bibliography), the most important area of teaching and research activities are concerning the real-world experimental investigations. The majority of support obtained by the CSCI group within the last years was used for design and development of semi-industrial-scale pilot plants treated as real-world control plants. All of these plants include real-world industrial measurement and control equipment. A new area of R&D activity deals with the application of the Internet both for development of virtual control systems and information-layer supervisory control systems based on TCP/IP and OPC connection; as well as for distribution of real-world control data from control plants by the Internet. The newest research activity deals with agent-based and holonic technology applied for intelligent and mobile control and monitoring.

The following notes present chosen pilot plants and research results.

Industrial-scale heat distribution pilot plant

M. Metzger, P. Łaszczyk, K. Pasek

The industrial scale heat distribution pilot plant was developed and worked out at the laboratory of the CSCI group in the nineties. This pilot plant has a structure of a real heating system with flexible connections of the heat receivers. This structure itself was developed on the basis of the real industrial heat distribution plant and it consists of three heat exchangers of different type, the mixing tank, the electric water heater and the several water circuits. In the primary circuit the water is pumped from the electric heater to the spiral-tube heat exchanger HE1, which then transfers a part of the heat energy to the secondary circuit consisting of the plate-type heat exchanger HE2 and of the double-pipe heat exchanger HE3. The outlet water from the heat exchangers of the secondary circuit finally flows into mixer.

Nowadays the optimal control of heat distribution plants is the important challenge in the field of the energy saving strategy. The flexible structure of our pilot plant allows us to operate the installation in the most important classical modes. Moreover, both the classical PID and the advanced low-level control algorithms, relevant to the chosen operating mode, can be applied to the plant and compared. There is also the possibility of the application of the high-level monitoring and SCADA systems, both classical and advanced based on the artificial intelligence.

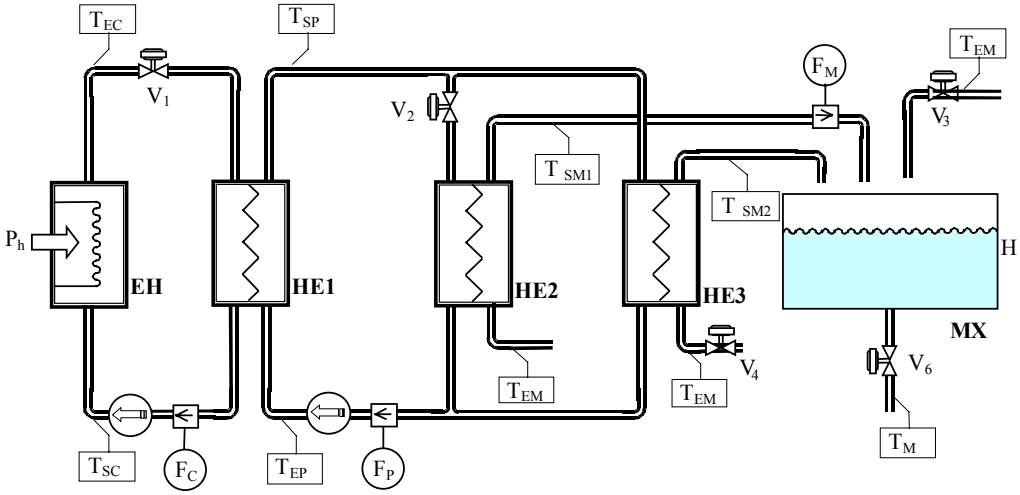


Fig. 1. Heat distribution pilot plant.

Figure 1 shows the location of the temperature sensors applied to collect the measurement data of the controlled variables. There are also two additional controlled quantities: the water flow rate F_C in the primary circuit and the water level H in the mixer. It is possible to use six valves as the control variables.

Fig. 2. Heating network

Neutralization pilot plant

M. Metzger, D. Choiński

The modern neutralisation pilot plant has been designed and worked out at the laboratory of the CSCI group. The installation itself is a scale model of a real industrial neutralisation plant with two neutralisation reactors (stirred mixers) and with flexible connections of the injection pipes. There is also a possibility to carry out the in-line neutralisation process with the application of the in-line injection. The design features allow this installation to be considered as a first stage of the complete neutralisation and biological wastewater treatment plant that has been developed at our laboratory.

The simplified scheme of the neutralisation pilot plant is presented in Fig. 1. Three real-world industrial dosing systems with metering pumps from Milton Roy were chosen to dose the reactants (acid and base) into the reactors. The especially designed system of two reactors was manufactured by Hydro-Eco-Invest. The three-input, three-output selector allows us to distribute the liquids into three separately chosen points of installation. The system of two stirred reactors is the main part of the plant. Each reactor has two injection points and is equipped with industrial pH-meter from Hydro-Eco-Invest. The remote pH measurement system consists of the pipeline, the peristaltic pump from Masterflex, the flow meter from Cole-Parmer and flow-through cell manufactured especially for this plant. Injection T-connector allows us to provide the in-line injection (in-line neutralisation process). The flexible pipeline system allows us to obtain different structures of the plant.

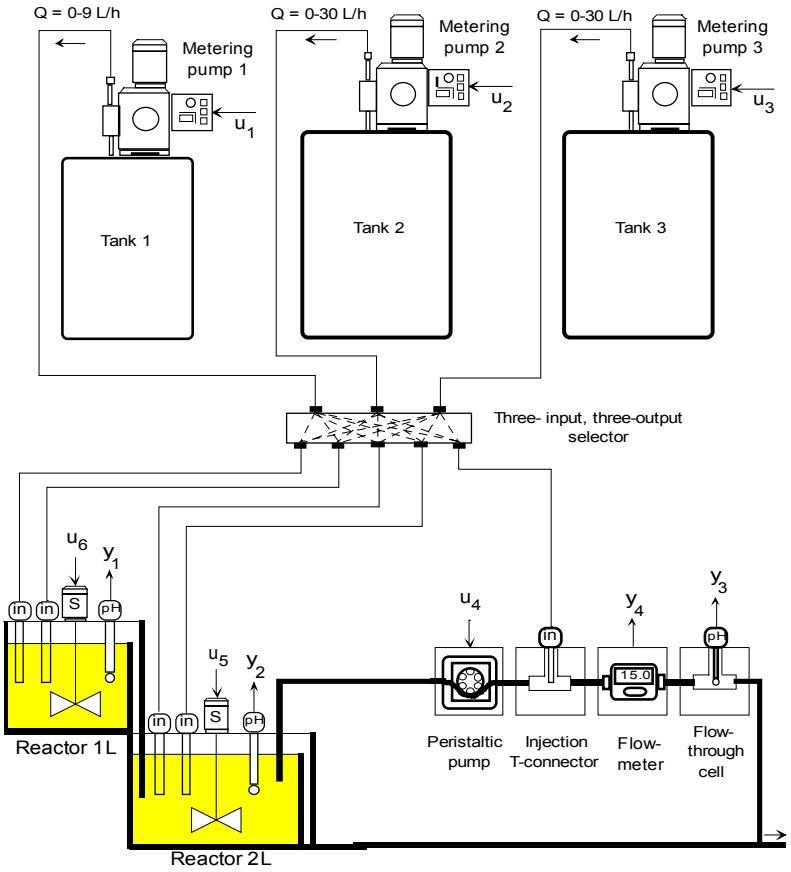


Fig. 1. Neutralization pilot plant with flexible tubing connections.

The possible structures cover (but are not limited to) the following:

- Neutralisation process in the reactor 1L,
- Neutralisation process in the reactor 2L,
- Two-stage neutralisation process in two reactors (1L and 2L),
- Neutralisation process in the reactor 2L with controlled (pH - controlled) disturbation in the reactor 1L,
- Two-stage process of the neutralisation (in the reactor 1L) and the stabilisation (in the reactor 2L),
- Neutralisation process in the reactor 2L with remote pH measurement,
- Two-stage neutralisation process in two reactors (1L and 2L) with remote pH measurement,
- Neutralisation process in the reactor 2L with pH-controlled disturbation in the reactor 1L and remote pH measurement,
- Two-stage process of the neutralisation (in the reactor 1L) and the stabilisation (in the reactor 2L) with remote pH measurement,
- In-line neutralisation process,
- In-line neutralisation process with pH-controlled disturbation in the reactor 2L,
- Two stage neutralisation process (in the reactor 2L and in-line neutralisation),
- Three-stage process of the neutralisation (in the reactor 1L), the stabilisation (in the reactor 2L) and the in-line neutralisation.

The monitoring and control equipment consists of the FieldPoint™ modular distributed I/O system and of the specialised software: LabVIEW™ and LabWindows/CVI™ - both from the National Instruments. The pilot plant was in full operating conditions and ready for research experiments at the end of the 2000.

Fig. 2. View of the pilot installation.

Pilot switcheable SBR and SOCP processes for biological wastewater treatment

M. Metzger, D. Choiński, W. Nocoń

The classical continuous activated sludge process should contain at least two (aerobic and anoxic) reactors for both carbon and nitrogen removal. Although such classical processes are widely used, sequentially operated continuous processes (SOCP) and sequencing batch reactors (SBR) are an attractive alternative. In these processes, carbon and nitrogen removal can be accomplished in only one bioreactor in which the aerobic and anoxic phases are periodically sequenced.

In comparison to classical continuous biological processes when the process can be carried out without any control system, the sequences of the periodically operated process must be controlled and thus the development of the SBR (or SOCP) as a real-world pilot plant can be very interesting for the real-world experiments.

During the year 2000 a great effort has been done to design and develop the pilot plant. A special 30-liter SBR with appropriate fitting system as well as the pH, Redox and dissolved oxygen continuous measurements were carried out. The first control experiments dealing with the hydraulic operations (fill, mixing, aeration and draw) started at the 2001.

In the 2002, a new idea has been developed. It can be noticed that with very little financial costs the SBR reactor can be augmented with secondary clarifier and in that way we can obtain the SOCP process in witch the same reactor used as SBR can be applied as continuous aerator for sequentially operated continuous process.

The simplified scheme of the process is presented in Figure 1 while the view of the pilot plant is presented in Figure 2. The control and monitoring with visualisation of the process are based on the new equipment from the National Instruments and from the Rockwell-Allen-Bradley. The spectrophotometer and COD reactor from the Hach allows us to analyse COD, nitrates and nitrites as well as ammonia nutrients according to the international standards for wastewater measurements.

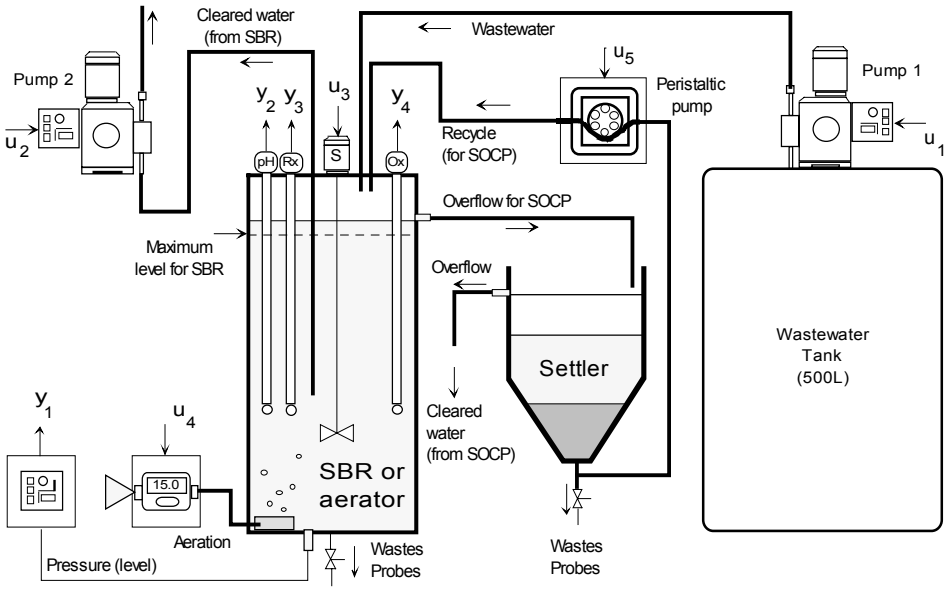


Fig. 1. An idea of switcheable SBR and SOCP processes for biological wastewater treatment.

The first control experiments dealing with the hydraulic operations (fill, mixing, aeration and draw) and with switching between SBR and SOCP processes will start at the beginning of the 2003. After that, in the 2004 first growth of the appropriate microbiological cultures and the experiments of the carbon and nitrogen removal with synthetic municipal wastewater have been carried out.

Fig. 2. View of the newest pilot installation.

In the 2004, a new extension of the pilot plant has been developed. Figure 3 shows the newest extension of the plant.

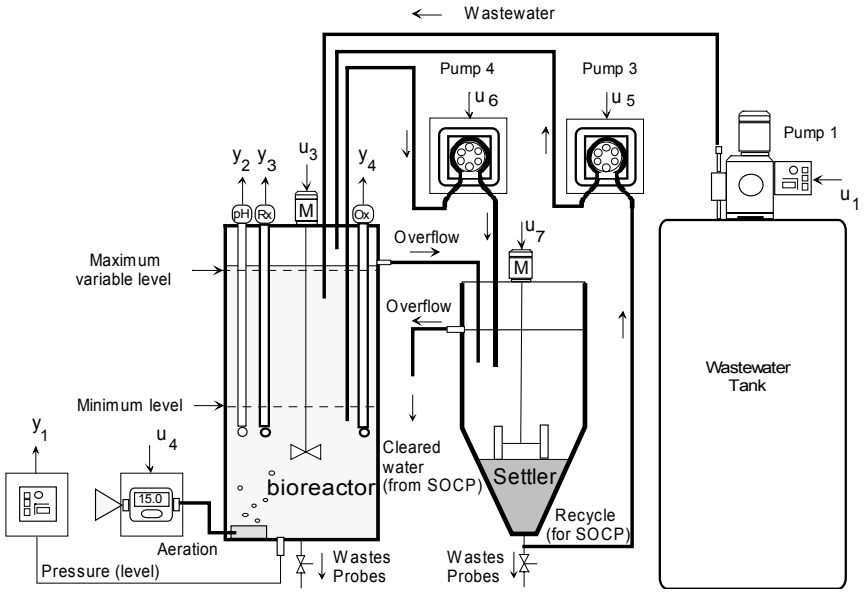


Fig. 3. Architecture of the enhanced pilot SOCP with a possibility of the biomass concentration control.

The bioreactor is fed with synthetic wastewater from a wastewater tank using Pump 1. Although an overflow from the reactor to the settler is physically realized, when the volume of the reactor should be kept at a lower level, the peristaltic pump (Pump 4) is used to feed the settler. This pump, together with a pressure transducer that is used to measure the reactor level, are both used to maintain the appropriate level in the bioreactor. The bioreactor is aerated using air pump (u_4). The recycle of condensed sludge from the settler to the bioreactor is realized by another peristaltic pump (Pump 3). Two mixers are available: one (M1) used to maintain uniform sludge concentration throughout the bioreactor, and the other (M2) used to gently mix the bottom part of the settler. Appropriate manipulations with both flows between the reactor and the settler as well as with mixers speed allows us to, for example, temporary storage of the sludge majority in the reactor or in the settler.

Pilot exothermic batch and continuous chemical reactor

M. Metzger

Both the continuous and batch stirred tank reactors, considered as the control plants, are ones of the most frequently investigated processes. The classical irreversible $A \rightarrow B$ exothermic reaction, taking place in the reactor, is a great challenge faced by the automatic control engineers due to the nonlinear and non-stationary behaviour of this process. A very interesting control problem deals with the working-point regime of this process in which an open-loop operation is unstable. Therefore, for this kind of processes, there is a need to develop the sophisticated low-level control algorithms and then to compare their performance with the classical PID controller.

The idea of the structure of this pilot plant (see Fig. 1) is based on the following.

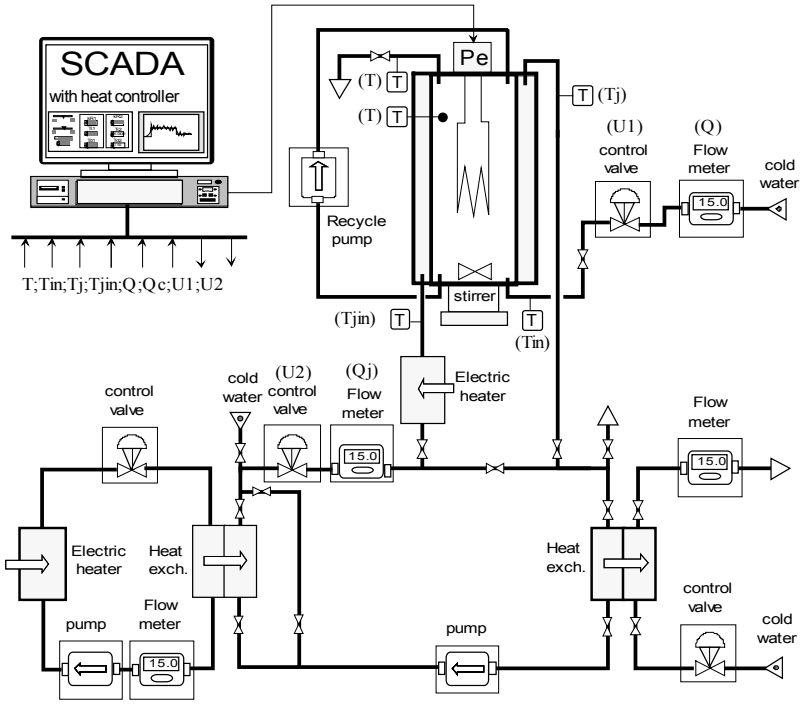


Fig. 1. Simplified scheme of the pilot plant.

In the real-world plants the equipment for measurement of the substrates and products concentrations are very expensive and in majority of cases it is impossible to obtain the continuous or discrete measurement data of these parameters. Therefore only the inlet and outlet temperature can be considered as the controlled variables since the temperature can be easily measured on-line.

When only temperature measurement data is accessible and the temperature inside the reactor is the controlled variable, the process of the cooling of the exothermic chemical reactor with the application of the cooling jacket can be considered as the heat exchange process. Therefore it is possible to carry out the process only with the water inside the reactor tank. The heat, produced in the reactor due to the exothermic chemical reaction that should take place inside the reactor, can be simulated by means of the computer-controlled electric heater (see Fig. 1). This approach allows us to ensure the low costs of the experiments and to avoid the problem of the security standards due to the operating of the chemical reaction.

It is important to note that the temperature sensors, the flow meters and the control valves with actuators are the real industrial equipment – only the heat produced due to the reaction taking place is simulated.

A new pilot plant has been designed and carried out in the Control Systems and Control Instrumentation (CSCI) Group at the Institute of Automatic Control. This plant includes the hybrid stirred tank reactor with electric heater simulating the heat generated by the reaction.

The pilot hybrid stirred tank reactor is designed in a special manner that it will be possible to incorporate this new stirred tank reactor to existing heat distribution installation. The simplified scheme of the extended pilot plant is presented in Figure 1.

It is possible to connect the jacket of the chemical reactor into the heat distribution pilot plant to ensure the possibility of adjusting the inlet jacket temperature and the possibility of heating and cooling of the reactor jacket by means of two existing heat exchangers (see Fig. 1).

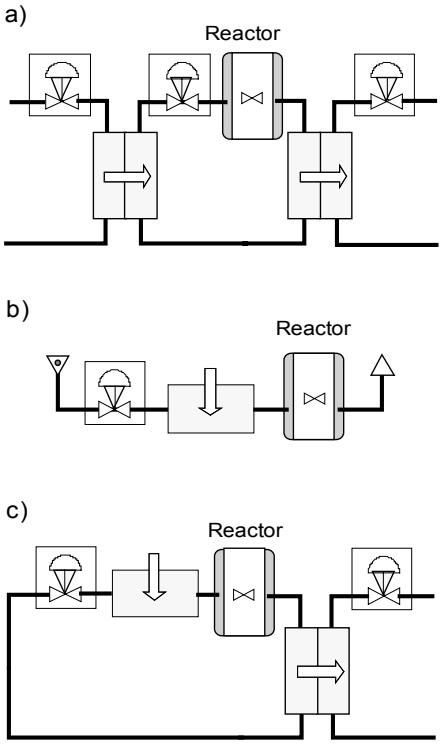


Fig. 2. Most important possibilities of the jacket heating and cooling.

The reactor must be heated by the jacket for initialisation of the reaction, whereas it must be cooled when the exothermic reaction takes place (which will be simulated by controlled heater in the reactor).

The switching valves in the system presented in the Figure 1 allow to operate the reactor as a part of the heating circuit (see Figure 2a) and as an independent plant with cooling circulation from municipal water supply (see Figure 2b). For quicker heating the additional thermal source can replace heat exchanger (see Figure 2c). In all cases the reactor itself can be operated in the batch mode or in the continuous mode. The reactor with control equipment is shown in Fig.3.

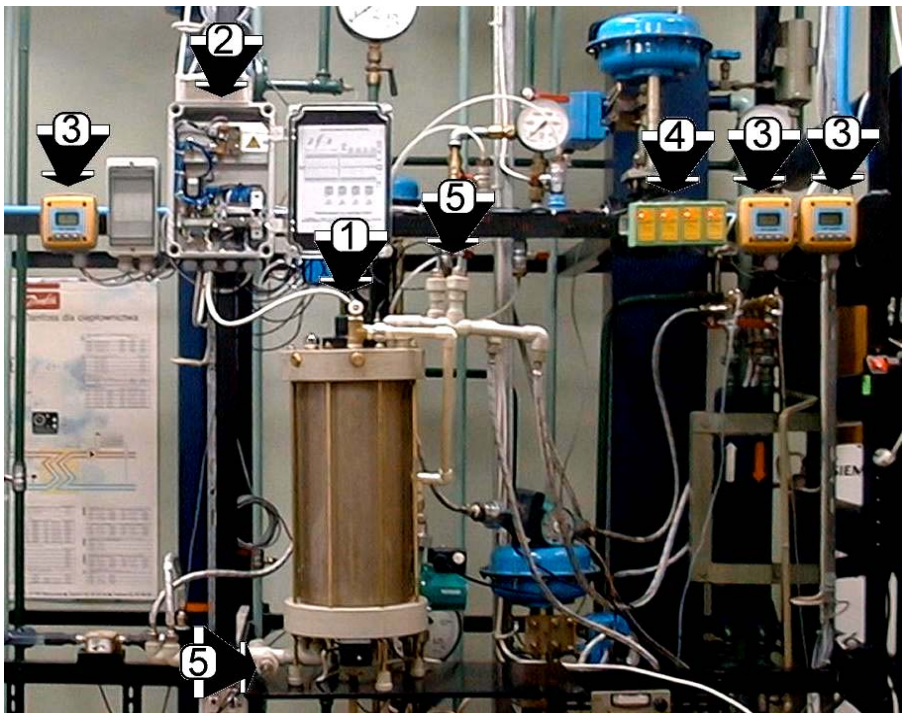


Fig. 3. Pilot plant with electronic control equipment. 1) the reactor with electric heater; 2) power controller for electric heater and signal transmitters for temperature sensors; 3) programmable smart transmitters for flow sensors; 4) power supplies for current loops; 5) temperature sensors at the inlet and outlet of the reactor and its jacket.

The simulated part of the pilot plant represents the value of the power P_e, which should be calculated in the real-time as control variable.

$$P_e = V[\Delta H_A r_A(T) c_A^n + \Delta H_B r_B(T) c_B^m] \tag{1}$$

where c_A, c_B, r_A, r_B should be also calculated in the real-time from equations (1,2,5). Simple Euler method for solving equations (4,5) in the real-time is sufficient to use.

Such a controller has two real-world inputs – T and Q, one real-world output P_e, and a set of setting parameters, which appropriate values determine the behaviour of the process (see Fig. 4). Furthermore the controller allows to observe (simulated in the real-time) responses of concentrations c_A and c_B (because these responses must be anyway simulated for calculation of P_e).

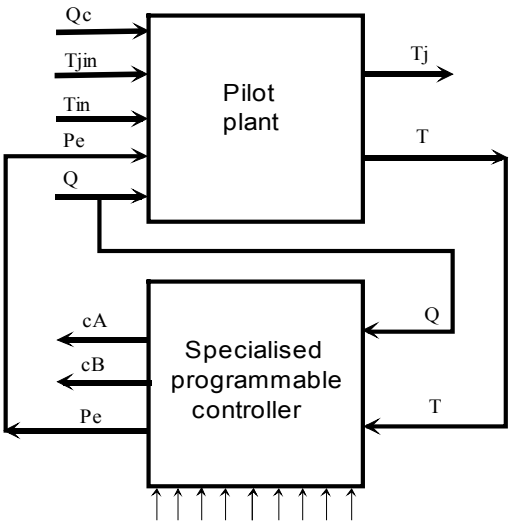


Fig. 4. The hybrid reactor as feedback control system for creating desired dynamic behaviour.

Batch sedimentation pilot-plant

M. Metzger, W. Nocoń

Sedimentation is one of the most widely used techniques of separation in the chemical, mineral and wastewater treatment processes. The process takes place in a settler, where solid particles suspended in a liquid are settling downward, leaving clear water at the top of the settler and concentrated slurry at the bottom. This downward movement of solids is caused by gravitational force. Two types of the sedimentation process can by distinguished: continuous sedimentation (solids are continuously fed into the settler) and batch sedimentation (the settler is filled with liquid containing suspended solids and settling occurs afterwards).

An experimental batch sedimentation pilot-plant has been designed and developed in the Control Systems and Control Instrumentation Group at the Institute of Automatic Control. This pilot-plant is schematically shown in Figure 1, and its view is shown in Figure 2. The sedimentation process takes place in the settler where the level of liquid is measured by a pressure transducer (y_2). The cleared water is removed from the settler by a Masterflex peristaltic pump (u_2: on/off or continuous flow control) and the suction nozzle is mounted on the float. A turbidity sensor (y_1) is mounted on the same float and is used to indicate the presence of solids in the water being removed form the settler. The sensor itself was developed in the CSCI group is designed to be a low cost indicator of sludge blanket presence. The cleared water is fed into the supply tank from which it can be returned to the settler by a second pump (u_3: on/off). A stirrer is provided (u_1: on/off) to stir the suspended solids inside the settler. The measurement signals and control variables are accessed in a PC computer using the FieldPoint Modular I/O System.

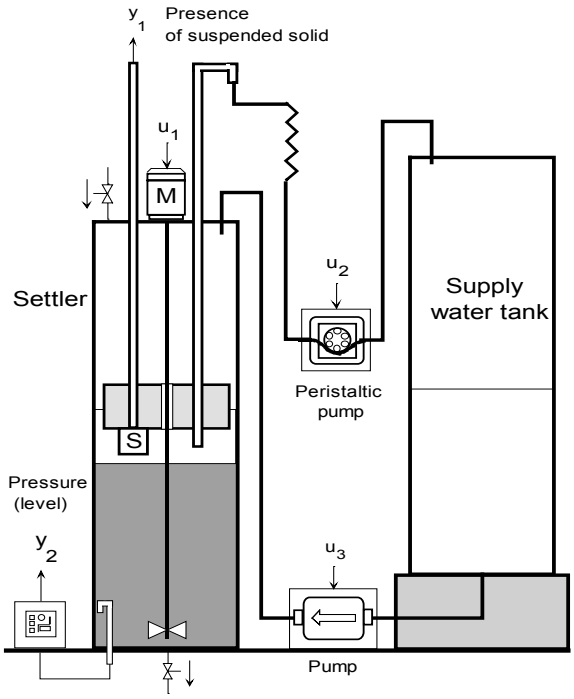


Fig. 1. Batch sedimentation pilot plant.

This pilot plant is used to design and test different methods and algorithms for control of the clearing processes in batch settlers (including identification of sedimentation process parameters from the simple measurements, calibration of simple sensors and optimisation of the clearing processes). Moreover, it serves as an excellent educational example of non-trivial real-world processes with highly non-linear dynamics.

Fig. 2. View of the sedimentation pilot plant.

Architecture of network-based Distributed Control Systems for CSCI pilot plants

M. Metzger

Over the past two decades decentralised, distributed control systems appear as a well-agreed standard in the automatic control. The big world producers offer very expensive, different communication network systems for all layers of control. One of the most important steps in the development of real-world control system is this system testing. Control software and control equipment can be tested on the real-time simulators. However, the most important tests should be carried out on the real-world plants. Although testing control equipment on the semi-industrial scale pilot plants is more expensive than on the simulators, it is also more realistic.

A big effort was made over the last years in the CSCI group for design, development and building of semi-industrial scale pilot plants treated as real-world control plants. All of these plants include real-world professional industrial measurement and control equipment. The control equipment allows developing distributed control systems basing on operating, control and device levels of data transmission.

In the CSCI group we start building two real-world distributed control systems. Both are designed for control of our pilot plants.

The first system (see Fig.1) is based on hardware and software from the National Instruments.

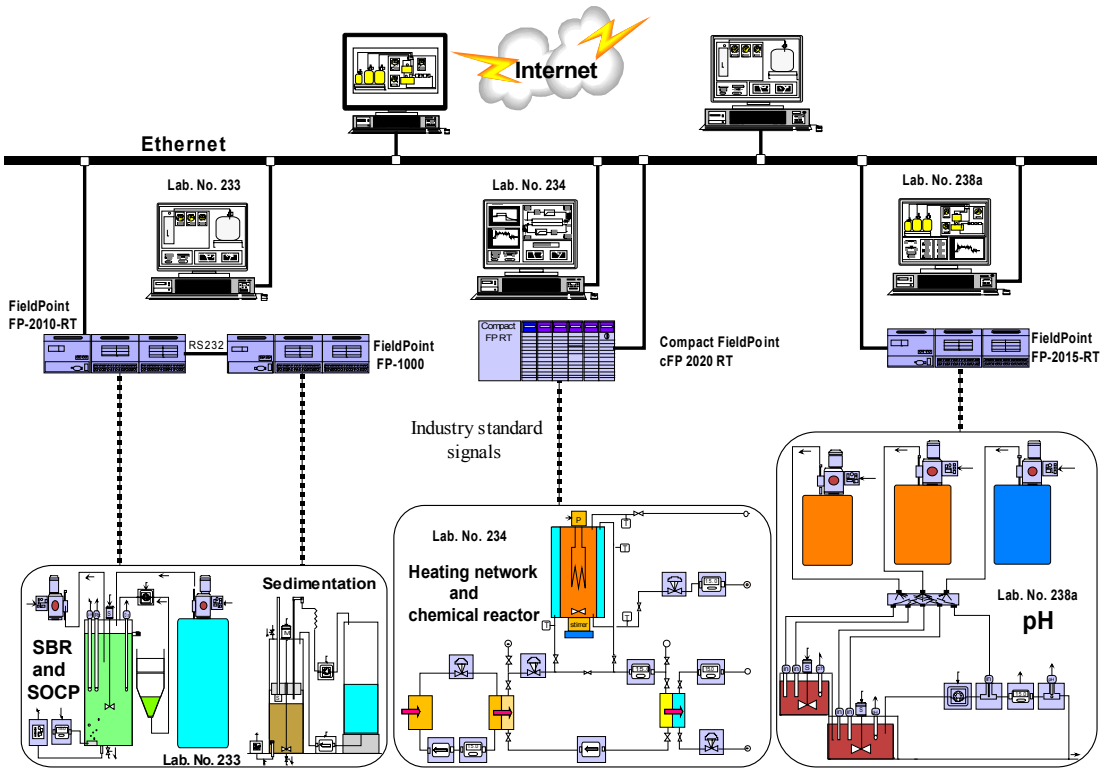


Fig. 1. Architecture of the distributed control system based on the FieldPoint equipment.

This system exerts only one standard of data transmission based on the Ethernet. The SS2 Switch 3300/100Mhz equipment allows communication with an application of TCP/IP and OPC protocols.

Three FieldPoint type controllers (one of them is the newest FP-2010 controller with hard real-time operating system and the www capabilities) and appropriate data acquisition boards allow distributed control and monitoring. The system can be programmed with an application of the LabVIEW standard, and that is why it will be very user-friendly for research and teaching. The supervisory information system, presented in Fig. 1, will be an experimental plant for comparative investigations of transmission possibilities.

The second system (see Fig. 2) is based on another idea. Namely, it is an industrial system from one of the world's most-developed systems from a big producer.

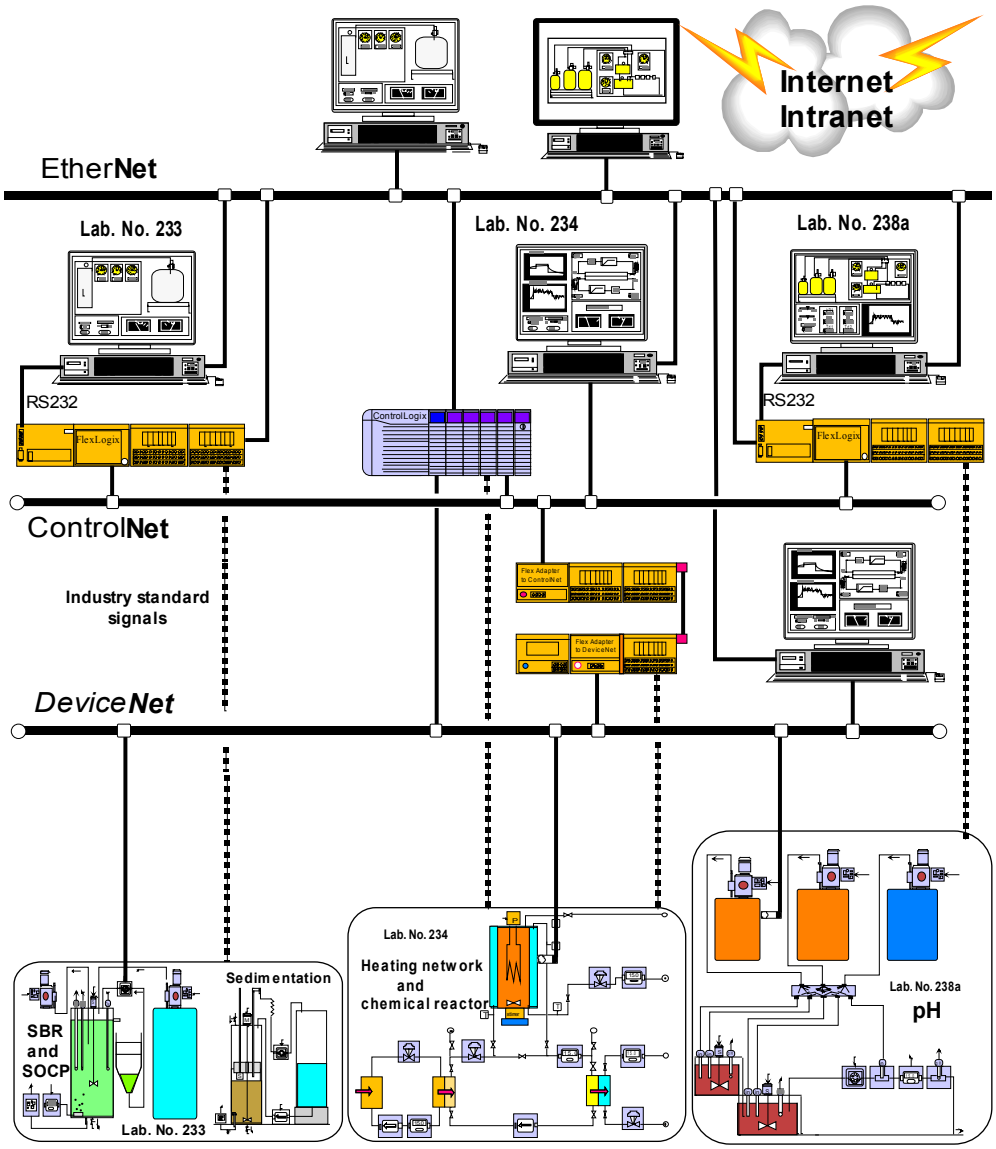


Fig. 2. Architecture of the distributed control system based on the Logix system.

The Logix system from Rockwell-Allen-Bradley includes three controllers: one ControlLogix and two FlexLogix as well as one Flex I/O for distributed data acquisition.

The Rockwell system includes three-level open architecture of data transmission: namely, the information, control and device levels. The Ethernet, ControlNet and DeviceNet standards offer services for these levels respectively.

Although the hardware and the software of the Logix system demand more sophisticated knowledge but also show the problems in the area of designing real-world, multi-level-network distributed control systems.

Over the last years the appropriate control and information equipment has been completed. Both systems were designed and carried out in the form presented in Fig. 1 and Fig.2. The members of the CSCI group as well as our graduate students and doctorants have performed several aplications.

The PCS7 (Simatic S7) distributed control system from Siemens is very frequently used in the European industry. Hence, this system should be included in the educational schedule. The set of the Simatic S7-300 controllers connected by the industry standard signals with appropriately equipped (I/O DAQ boards) computers are the basis of student exercises in the specialised laboratory.

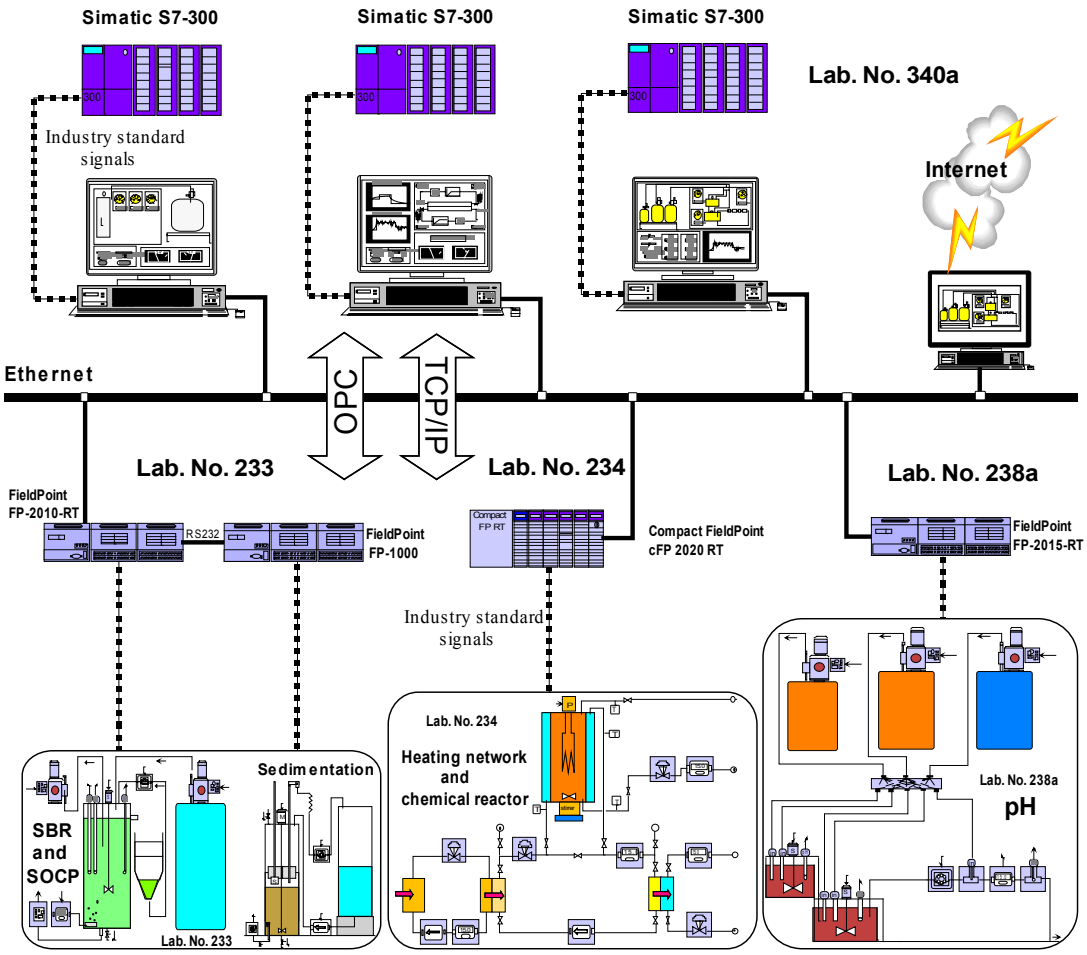


Fig. 3. Architecture of the distributed control system based on the Simatic system.

It will be very interesting to apply also the PCS7 Simatic system (although not connected to our pilot plants) as the third distributed control system for these plants. A concept of not too much complicated, Intranet-based communication can solve this problem. Using the FieldPoint system as distributed field I/O moduls (connected to the pilot plants) we can connect digitally by the Ethernet the PCS7 Simatic controllers to our pilot plants. The architecture of the distributed control system based on the transfer data between Simatic and FieldPoint systems is presented in Fig.3.

Five remotely controlled web-cams augment the capabilities of the control and monitoring system based on DCS. Those capabilities can be very useful especially for educational purposes

Real-time control strategy for sequentially operated continuous wastewater treatment process

D. Choiński, W. Nocoń, M. Metzger

The substrate reduction depends on many factors characterising biological growth rate. The simulation studies show that substrate reduction strongly depends of the initial biomass concentration. Hence, a possibility of changing the biomass concentration in the bioreactor can be very attractive for enhancing flexibility of the wastewater treatment processes especially in the presence of large fluctuations of the inflow loads. A real-time sequential control strategy based on such idea has been developed and realised for an enhanced sequentially operated continuous process. Real-world experiments were performed on semi-industrial pilot plant presented above. This application is presented in this note.

The principle of controlling the biomass concentration in the bioreactor is based on the recognition that microorganisms satisfy their maintenance energy requirements in preference to producing additional biomass. In a substrate limited environment it is reasonable to expect that microorganisms' allocation of carbon source will preferentially be oriented towards satisfying their maintenance energy requirements and not towards their anabolic functions (biomass generation). The consequence is that the biomass production decreases proportionally to the biomass concentration. A method for reducing the generation of excess biomass during wastewater treatment has been presented and was based mainly on control of the recycle of biomass from the settler back into the reactor.

In a steady-state operation of the wastewater treatment plant it is assumed that the load variations are relatively low. The dissolved oxygen set point level is selected so that the nitrification process is assured, and the recycle flow is selected so that the appropriate sludge age is maintained. For this reason, using the recycle flow as a manipulated variable for the biomass concentration control is not advised.

In this note an alternative method for controlling the biomass concentration is presented. It is based on the fact, that during steady state operations, the biomass concentration is maintained at a constant level. If however a need to alter the biomass concentration arises, a certain operation will be performed that will sequentially change this concentration.

In a classical approach, the continuous wastewater treatment plant is configured as presented in Fig. 1.

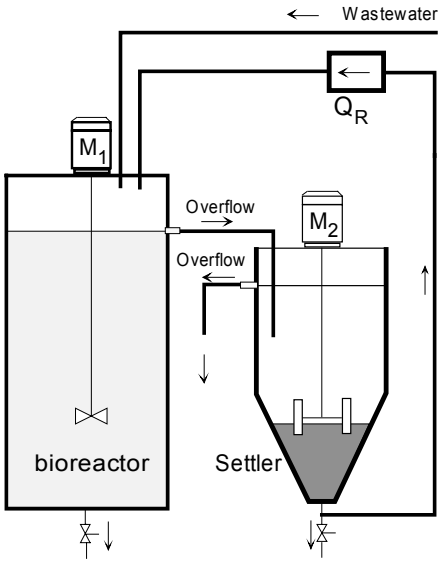


Fig. 1. Working point in classical architecture.

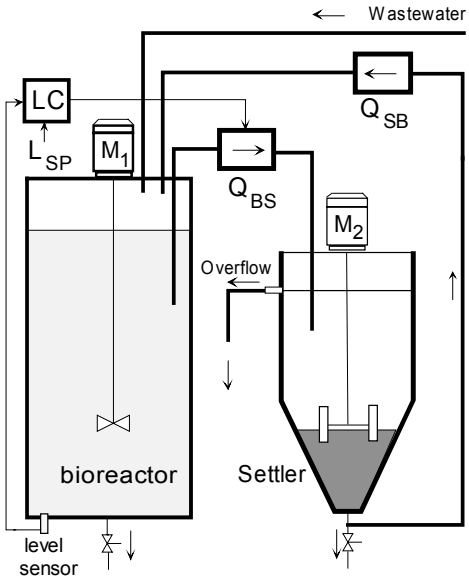


Fig. 2. The same working point in enhanced structure.

The plant consists of two separate tanks: bioreactor in which all the biochemical reactions are taking place, and the settler in which the separation of activated sludge flocs from water occurs. The wastewater reaching the plant is fed directly into the reactor. The volume of the bioreactor is assumed constant, which is usually realized by an overflow linked to the settler. The thickened sludge from the bottom of the settler is fed back into the reactor using a recycle pump, while the clarified water is removed by an overflow are directed out of the wastewater treatment system. In the pilot-plant used in the experiments, the recycle flow and the settler mixer are operated quasi-continuously using, the pulse-width modulation (PWM) control.

The proposed control scheme implies the following requirements:

- the bioreactor must possess the capability to operate with different volumes and a possibility to operate in a batch mode,
- the settler, being a constant volume tank, must possess the capability to operate with a varying solid retention time.

The first requirement is fulfilled by using an explicitly controlled pump instead of an overflow (Fig. 2). Level in the reactor is measured and a simple control algorithm (LC) is applied to maintain a constant level inside the bioreactor. Therefore, in a steady-state operation, the reactor works with a constant volume, but the set point level (L_{SP}) may be changed if needed. The batch mode may be realized for example by setting the Q_{SB} and Q_{BS} flows to zero (switching the pumps off) and by stopping the mixer (M1) in the bioreactor in order to commence the settling phase.

The second requirement (a settler with a varying solid retention time) may be fulfilled by applying a gentle mixing at the bottom of the settler. The mixer (M2) is usually used to maintain a unified thickening process. However, it may also be used to change the solid retention time by changing the mixing speed (for a longer solid retention time, the mixing speed must be increased).

When the mentioned requirements are fulfilled the appropriete sequences for changing biomass concentration (X) inside the reactor may be applied.

For example, when a need to condense the biomass in the reactor arises, the following sequence of operation is carried out (Fig. 3):

1. The overflow pump (Q_{BS}) is switched off.
2. Mixing in the bioreactor (M_1) is stopped.
3. Mixing inside the settler is also stopped to perform a rapid thickening of the biomass at the bottom of the setter.
4. When the thickening process in the settler reaches a satisfying level, the recycle pump (Q_{SB} flow) is used to move the biomass into the reactor.
5. Because the mixer (M_1) in the bioreactor is switched off, the sedimentation process occurs and a clarified zone at the top part of the reactor is created enabling the reduction of reactor volume without reducing the amount of biomass.
6. After a certain period of time that is required for the whole biomass to settle (including the biomass pumped from the settler), a new level set point is generated and the overflow pump (Q_{BS}) is switched back to it's normal operation. The new set point may either be the same as the previous one or, if higher concentration of biomass is needed, the new set point may be lower.

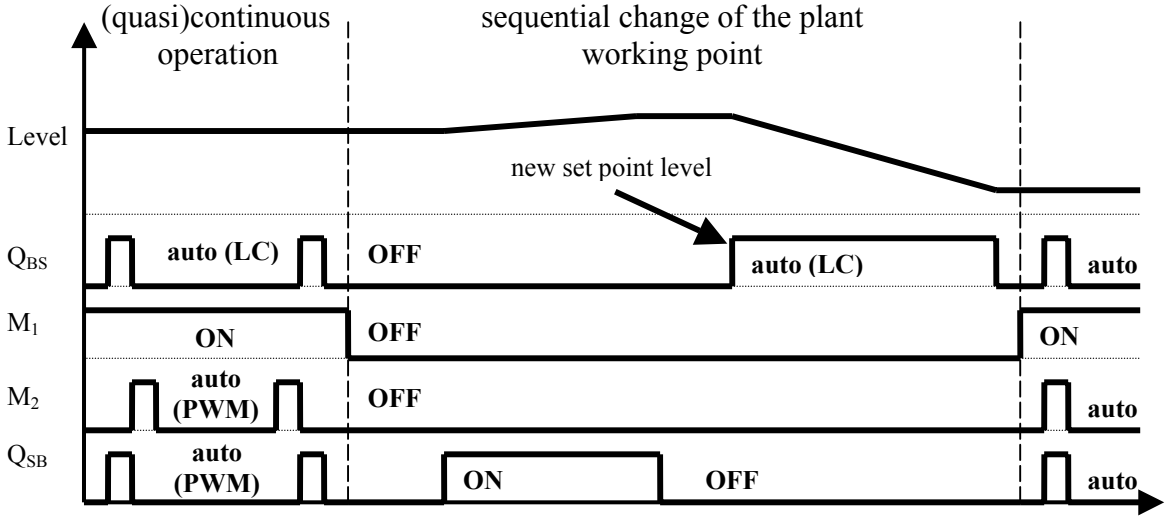


Fig. 3. Sequence for increasing biomass concentration.

The control system for the pilot-plant is realized using the distributed control system build and operated at the CSCI group (see precedings note). At present, the FieldPoint 2010 controller, programmed using LabVIEW, is used. Utilization of Alan-Bradley Flex-Logix controller is also possible. The HMI panel of the SCADA application is presented in Fig. 4. In addition to realizing the control logic, this application allows manual control, data recording and an Internet-based remote access to the pilot-plant.

The purpose of the first experiments was to prove that activated sludge process performance control by changing the biomass concentration in the bioreactor is possible. The standard operation of the plant requires the dissolved oxygen in the reactor to be controlled at different set points. A set point of 1,5 [mg O_2/l] is applied to maintain aerobic conditions in the reactor while a set point of 0,1 [mg O_2/l] is applied to maintain anoxic conditions. The aerobic phase lasts for 100 [min] while the anoxic phase lasts for 90 [min].

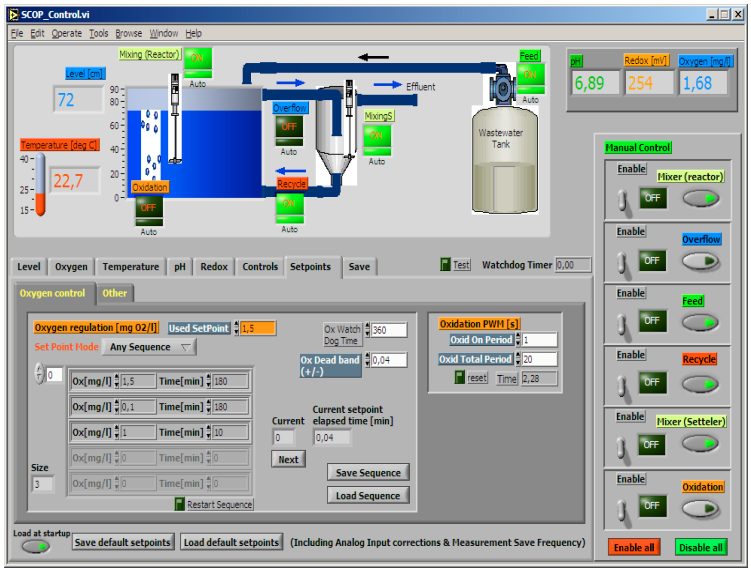


Fig. 4. HMI of the SCADA application used to supervise and control.

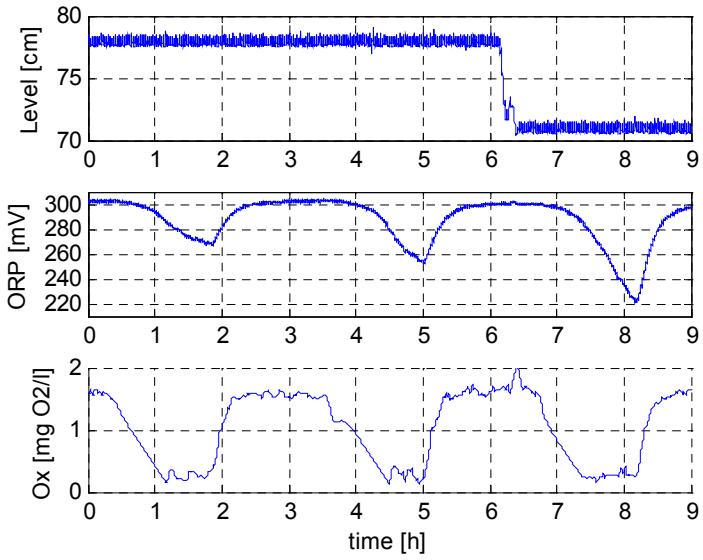


Fig. 5. Influence of the biomass concentration on the denitrification process.

In order to examine the influence of biomass concentration on the denitrification process, a sequence for increasing biomass concentration has been applied during the aerobic phase (Fig. 5). First, at about 3,5 [h], the sequence has been performed without changing the set point level in the reactor. It resulted in the biomass accumulated in the settler to be moved into the reactor. Such operation decreased the minimum ORP (oxidation-reduction potential) value attained during the anoxic phase by 16 [mV] (from 268 [mV] to 252 [mV]), thus intensifying the denitrification process. Secondly, at about 6,3 [h] another sequence has been applied, but this time, with a lower set point level and the biomass in the reactor has been condensed. This resulted in a drop of the minimum ORP value attained during the anoxic phase by an additional 30 [mV] (from 252 [mV] to 222 [mV]). Obviously, it must be stated, that in the experiment, substrate was not the limiting factor in the reactions. Example of the sequence performed is pictured in Fig. 6.

Fig.6. Presentation of the biomass manipulations. After the thickened sludge is pumped from the settler into the reactor, which results in a drop of level in the setter (right image) and a corresponding rise of level in the reactor, a new set point level is determined and reached by the controller. Mixing in the reactor starts (left image) and the system restarts it's normal continuous operation with a changed biomass concentration.

Based on real-world experiments a methodology for a sequential change of the continuous wastewater treatment plant has been presented. It modifies the operation of the WWTP in such a way, that when a need to change the biomass concentration in the bioreactor arises, a certain sequence of events may be applied. Hence, a possibility of using the biomass concentration as a control variable is provided. In addition, the presented methodology, does not interfere with the sludge age control by leaving the recycle flow as an independent control variable. In other words, the presented methodology posses a potential for increasing the controllability of the wastewater treatment plant. These results (obtained in the 2004) are very interesting for teaching purposes taking into consideration participation of the CSCI group in the biotechnology field of education.

B-BAC: the Model-Based Adaptive Control Methodology for a Wide Class of Industrial Processes

J. Czeczot

For the last decades the methodology of the model-based nonlinear control has become the subject of growing interest due to its ability to employ the process nonlinearities directly in the control law. This approach usually provides significant improvements over linear control techniques but there is one limitation: we have to know the nonlinear model of the process. This model can be physical or empirical but in both cases when the significant improvement of the control performance is expected, the adaptability

should be employed in the control law to ensure its robustness. The adaptability itself usually consists in the estimation of the model parameters, included in the control law, and therefore the complete form of the mathematical model must be given. However, in majority of cases, when physical model is employed, there is a large uncertainty on the nonlinear part of the model. Moreover, the model parameters vary in time and due to this fact, usually there is a need to apply some sophisticated multiparameter identification techniques on-line. Consequently, in such cases the very well known difficulties with identifiability and with the estimation convergence arise.

The approach, which is suggested and called Balance-Based Adaptive Controller (B-BAC), combines simplicity and generality, that are characteristic of the classical PID controller, with very good control performance and robustness resulting partially from its adaptability and feedforward action and partially from the characteristic properties of the methodology itself. The B-BAC is dedicated to control a wide class of technological processes and its generality follows from the fact that the control law is derived on the basis of the simplified part of a nonlinear physical model of a process, namely on the general balance-based dynamic equation describing a controlled variable. In this equation the nonlinearity, resulting from a number of reactions and/or heat exchange phenomena taking place due to a process, is represented by the only one time varying term. Moreover, this term can additionally represent the modelling uncertainties and inaccuracy. Its value is not measurable and thus it must be estimated on-line. However, since there is only this one parameter to estimate, it can be easily managed by the recursive least-squares procedure. This approach allows us to avoid common difficulties either with large uncertainty on the reaction and/or heat exchange kinetics and nonlinearity as well as with the multiparameter identification. Moreover, there is no longer a need to know the complete form of the physical model of the process. Only its part, describing the controlled variable, must be given in the simplified form.

If we want to apply the B-BAC methodology, there must be a possibility to define the control goal in the following way: one of the parameters characterising a process, defined here as Y(t) and called the controlled variable, should be kept equal to its pre-defined set-point Y_{sp}. Y(t) can be chosen as one of state variables (a component concentration or the temperature) or as a combination of two or more state variables. In a process a number of isothermal or nonisothermal biochemical reactions and/or heat exchange phenomena with unknown kinetics can take place. A process itself takes place in a tank with time varying volume V(t) [m^3].

The dynamical behavior of Y(t) can be described by the following well known general ordinary differential equation written on the basis of the mass or of the energy balance considerations:

$$\frac{dY(t)}{dt} = \frac{1}{V(t)} \underline{F}^T(t) \underline{Y}_F(t) - R_Y(t) \tag{1}$$

The vector product $\underline{F}^T(t)\underline{Y}_F(t)$ represents mass or energy fluxes incoming to or outcoming from the reactor tank. The elements of the vector $\underline{F}(t)$ are the combination of the volumetric flow rates and, consequently, the vector $\underline{Y}_F(t)$ is the corresponding vector to $\underline{F}(t)$ and its elements are the combination of the inlet values of Y(t) and of the value of Y(t) itself. $R_Y(t)$ is a positive or negative time varying term with an unknown expression form. It represents "one global reaction" including all reversible and/or irreversible reactions or heat exchange and/or production with unknown and nonlinear

kinetics that influence the value of Y(t). Let us note that in the case when Y(t) is a state variable, the equation (1) has a generalized and simplified form of a state equation describing Y(t) and taken directly from a mathematical model of a process. However, if Y(t) is a combination of two or more state variables, a number of state equations from a mathematical model must be combined together and rearranged to the form of the equation (1).

Once the equation (1) has been obtained, it can be a basis for the B-BAC under the following assumptions:

- the control variable must be chosen as one of the elements of the vectors $\underline{F}(t)$ or $\underline{Y}_F(t)$,
- the other elements of the vectors $\underline{F}(t)$ and $\underline{Y}_F(t)$ as well as the value of Y(t) must be measurable on-line at least at discrete moments of time or they should be known by choice of the user.

If the above requirements are met, it is possible to derive the following control law in the discrete form:

$$\underline{F}^{T,i}\underline{Y}_F^i = \lambda V^i\left(Y_{sp} - Y^i\right) + V^i\hat{R}_Y^i, \tag{2}$$

which, in fact, is a general form of the B-BAController. There is only a need to rearrange it to obtain the control law in the form that allows us to calculate the value of the control variable and then to implement it together with the estimation procedure. Let us note once again that our B-BAController is general since it is derived on the basis of the generalized form of the balance equation (1). It is also adaptive since the unknown term R_y^i is replaced by its estimate $\hat{R}_Y^i$. The estimation procedure is very simple to carry out and also general (since it is also based on the general equation (1)) and thus there is even no need to assume any form of a nonlinear expression describing the term $R_Y(t)$. Moreover, there is no need to know a complete mathematical model of a process. Both the B-BAC and the necessary estimation procedure are derived on the basis of the general mass and/or heat balance considerations in the form of the equation (1).

The generality of the B-BAC methodology ensures that it can be considered as an interesting alternative for the classical PID controller. The control performance of the B-BAC algorithm in the application to different technological processes was validated by computer simulation and can be found in [III.5 - III.9]. Moreover, in [III.4] the implementation of the B-BAC controller in the form of the LabView-based virtual instrument is presented.

The bumpless switching in the practical implementation of the B-BAC methodology

J. Czeczot

For every advanced control strategy, one of the most important problems resulting from the practical requirements is the bumpless switching between the manual and the automatic mode. Since the B-BAC algorithm must be implemented by the user, it is the user responsibility to ensure the bumpless switching in the particular implementation. In

(III.10) we suggest the general solution for this problem and then we present the simulation results of the application example, which illustrate the influence of this solution on the control performance.

Generally, the idea of bumpless switching can be put in one sentence: when the controller is switched from the manual into the automatic mode, the value of the control variable, calculated from the control law, must be the same as the value manually adjusted by the user. In the case of the adaptive model-based control approach it is ensured only if the internal model of a process matches a process itself with possibly high accuracy. In other words, the internal model must be updated on-line by adaptation technique not only in the automatic (closed loop) mode but also in the manual (open loop) mode. Thus, the estimation procedure, which provides the adaptation, must be carried out even if the controller is switched into manual mode.

In the case of the B-BAC methodology, the bumpless switching is always possible because the final form of the control law is based on the general and simplified dynamic model of a process (1). This model describes a process with high accuracy only if the value of the estimate $\hat{R}_Y^i$ is updated on-line with high accuracy both in the manual and automatic modes. Thus, the dynamic properties of the estimation procedure result significantly on the bumpless switching performance. Fig. 1 shows the accuracy of the open loop estimation for the example fermentation process in the presence of the indicated disturbances step changes for two different values of the forgetting factor α of the RLS estimation procedure. For α = 0.1 it is impossible to distinguish between the true value of R_Y and its estimate. The bigger value of α results in the slower convergence of the estimation procedure but in the steady state the true value of R_Y is always reached. The estimate $\hat{R}_Y^i$ always converges to its "true" value without any external excitation, even if the process is in the steady state and even when the initial value $\hat{R}_Y^0$ is chosen inaccurately. It leads us to the following conclusion. The estimation procedure ensures very good accuracy, which allows for the bumpless switching for the B-BAController. This accuracy depends on the value of α, which should be chosen to provide a good compromise between the resistance to the measurement noise and the estimation accuracy in the transients.

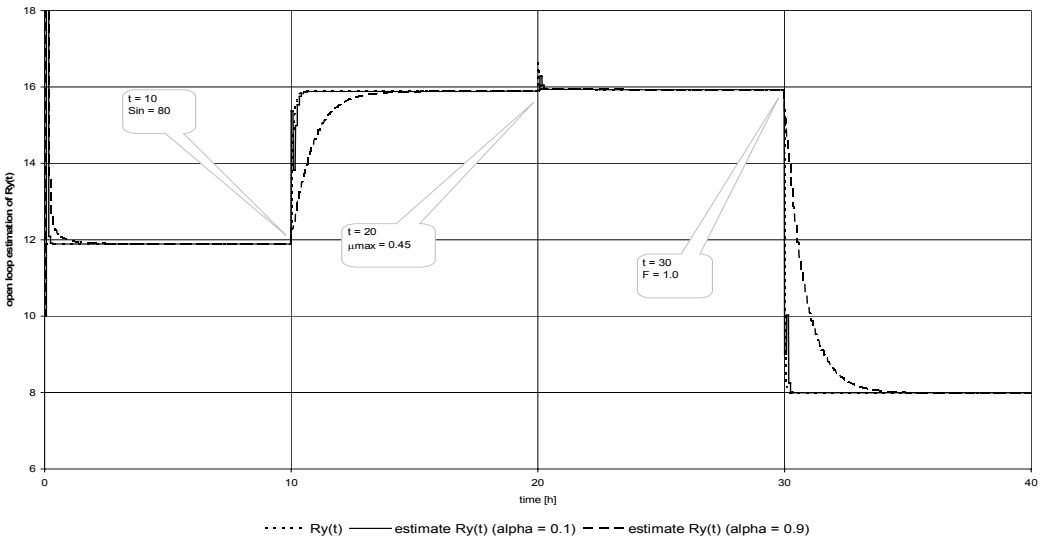


Fig. 1. Open loop estimation of the value of $R_Y(t)$ for the example fermentation process.

The additional conclusion deals with the choice of the initial value $\hat{R}_Y^0$ for the estimation procedure. Since in the practice the true value of the parameter R_Y is always unknown, it is impossible to choose the proper value of $\hat{R}_Y^0$. This improper choice results in the very significant inaccuracy and transient in the preliminary stage of the estimation. Thus, to avoid this difficulty, the B-BAController can be switched into the automatic mode only after the estimate $\hat{R}_Y^i$ has converged to its true value during the preliminary open-loop estimation stage.

To summarize, it must be stated that the properties of the RLS estimation procedure influence significantly not only the control performance in the closed loop. In the practical implementation in the form of the virtual controller or on a stand alone PLC device, these properties also condition the bumpless switching, which is very important in the case when the B-BAController is to be applied for the control of the real industrial plant. The estimation accuracy depends only on the choice of the forgetting factor α and the estimate always converges to its true value. This property allows us to formulate one of the most important advantages of the B-BAControl methodology: it provides the adaptability in the control law, which ensures very good control performance without any additional external excitation of a process. In other words, the estimation procedure provides very good accuracy even when a process is kept6 in the steady state.

Programmable pH measurement correction in application to control

K. Stebel, D. Choiński

Programmable pH measure correction monitor is computer based and in this sense it is a kind of Soft PLC. Good controller performance is important to process safety, product quality, and manufacturing costs. But once a controller is tuned, changes in the process can make a controller undesirably sluggish or aggressive, erratic or ineffective. Linear control algorithms work well in most cases. However, when nonlinear or nonstationary processes are considered, more sophisticated algorithms are needed to obtain satisfactory performance in long time periods. Process models are needed for synthesis of such nonlinear algorithms, but such models are usually complicated and computationally inefficient. Alternatively simple linear control algorithm may also be used but its performance has to be frequently evaluated. Maintains staff or an automated performance monitor can do it. The idea of performance monitor can be successfully applied to pH control process.

The concentration change of the solution around the pH electrode induces Henderson's potential. This potential is a disturbance in pH measurements and appears on the interface of solutions with different concentrations or different ion mobility. Local concentration of ions depends on ions activity that is possible to calculate using the Debye–Hückel theory but it is useful for effective preparing of solutions for the electrode calibration and not for on-line compensation. A statistical description of this structure is general enough for treating the equilibrium and dynamical case of ionic solutions.

The pilot plant installation considered in the work consists of three tanks for reagents and two coupled reactors. It is equipped with FeldPoint I/O system connected to the computer control system based on LabView. A standard PI control algorithm was

chosen for control. Usually, the controlled variable (CV) fluctuates around setpoint value. Statistically, it can be expected that the difference between time when CV<SP and the time when CV>SP is close to zero with some variance. Hence χ^2 test with one degree of freedom was applied to monitor difference of this time. It was assumed that the null hypothesis can be rejected when current chi-square value is grater than critical chi-square value with level α=0.1 of significance. When null hypothesis is rejected than controller SP is corrected. Correction is done if necessary only once at the end of each time window allowing controller and process to react on SP correction. Proposed idea was applied and tested on real-world pilot plant installation, sampled with 1-second interval.

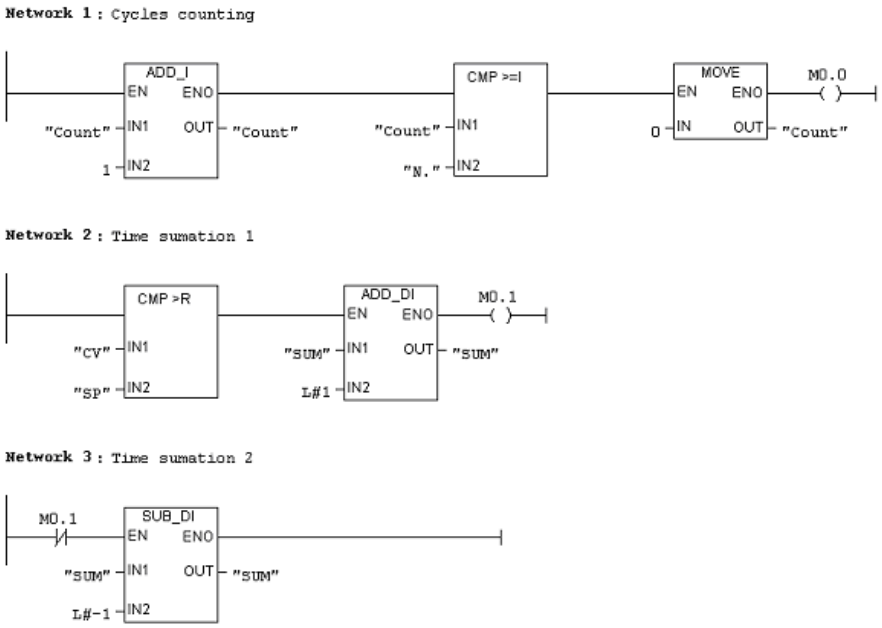


Fig. 1. Part of practical realization of the monitor module on Siemens S7-300 controller.

Application of the proposed programmable monitor was successful. It allows avoiding sophisticated nonlinear control. This monitor is a kind of a filter but it does not reduce information coming from measurement. It reacts only when statistically certain conditions are not fulfilled and correct SP to eliminate this influence. Another advantage of it is that, it may easily be implemented using a PC or a PLC (as an additional function that may be used in the existing systems, Fig.1).

Architecture of local-SCADA, remote-SCADA and docking virtual controllers for NI-FieldPoint-based control experiments via Internet

M. Metzger

The traditional controller proposed by most of the producers existing on the market is a self-containing instrument with a limited number of changing structure capabilities and with fixed user interface features (such as sliders, pushbuttons, gauges and indicators). All of these capabilities and features are designed and fixed by the producer.

Programmable modular controllers have similar features, in which the producer fixes programming capabilities.

The user-defined PC-based controller, while also equipped with appropriate professional features, can be a very interesting, low-cost alternative to controllers from commercial producers. We can refer to this kind of controllers as the virtual controllers. The NI FieldPoint system presented above is especially suitable for application of such virtual controllers running both on the PC computers and on the NI FieldPoint modules. Although the physical signals are connected to the system by the industry standard the virtual applications can also change data using TCP/IP connection.

At the CSCI group several virtual controllers have been developed in recent years for educational and research purposes such as for example single PI, PID controllers as well as advanced PFC, GMC and self-tuning PID controllers. All of them are equipped with standard professional features such as antireset windup and bumpless M/A switching. Finally virtual versions of professional programmable multifunction controllers such as for example well-known Sipart DR 24 from Siemens are also developed. All of these virtual controllers can be used for control in DCS presented in one of the preceeding notes.

An original conceptual contribution of this note deals with a new concept of easy performed control experiments on pilot plants with an application of virtual controllers (III.25).

The architecture of basic system for each of the processes (a pilot plant) is presented in Fig.1. The system containing several components connected by TCP/IP localhost data transmission runs on one PC or on one FieldPoint, which also ensures industry standard process connections. The central component – a SCADA system ensures process communication, monitoring and visualisation as well as can work as TCP/IP server for chosen signals. The control algorithms can be embedded in the SCADA system but it is more useful to connect different virtual controllers (only one in time) by localhost as docking controllers. In such a way the virtual controllers are applications separately developed and compiled. Although formally the TCP/IP connection is not time determined the localhost transmission do not change the control properties.

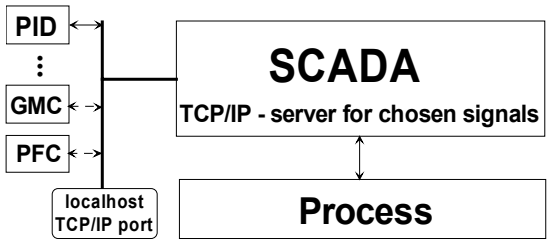


Fig. 1. Basic control system without remote possibilities.

The architecture of the control system with a possibility of remote performed experiments is shown in Fig. 2. The SCADA system and the virtual controller actually connected should be equipped with remote operating panels as http pages accessible by operator-defined ports and for operator-defined IP remote workstations. The control is locally performed, whereas monitoring, visualisation and setting can be carried out from other computers in the Intranet or by the Internet.

The experimenter can additionally observe some results of the control by web-cams (for example water level or LED lights on controllers) as well as can store the control

responses on HD for presentations. In principle such kind of experiments is reserved for staff only.

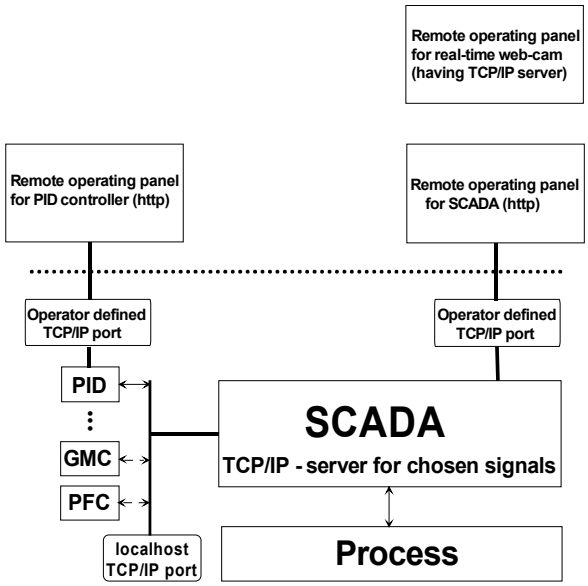


Fig. 2. Architecture of the control system with remote capabilities.

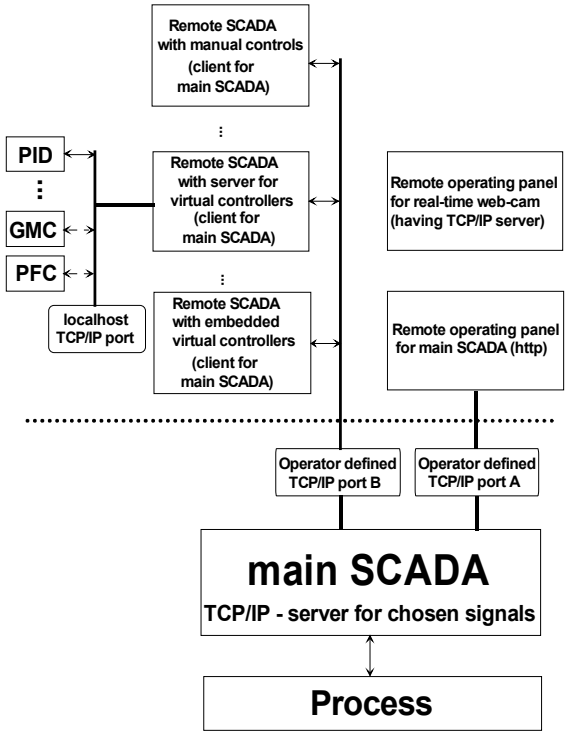


Fig. 3. Architecture of the system with remote experimenter-programmed components.

The architecture of the system dedicated for students or other distant experimenters is presented in Fig. 3. A professional main SCADA system has been developed by the staff. This SCADA system offers all controls and indicators in local mode as well as the web-based operating panel remotely for staff. This system has the possibility of staff-

defined signals (input/output) to be offered on the TCP/IP server using the staff-defined TCP/IP port. Only authorised students know the right sequence of signal transmission, the staff-defined number of the port, and staff-defined password.

Students should design and develop their own remote SCADA applications (as clients for main SCADA) for appropriate experiments. At the moment three typical remote SCADA systems can be distinguished: a SCADA system with manual controls, a SCADA system with embedded controllers and a SCADA system with the TCP/IP server for controllers programmed as separate executables (see Fig. 9). These controllers can be connected to the remote SCADA systems using also the "localhost" connection. The programming of such student's applications can be included in the teaching procedure. In the final phase, students perform remote experiments on the real-world pilot plants and observe and store some results of the control.

Although formally TCP/IP connection is not time determined as well as the control is performed remotely the control responses performed via the Intranet are the same as performed locally (the Internet change control behaviour but not dramatically for short horizon responses). The experimental investigations of influence of TCP/IP connections to control responses have been presented in (Metzger and Plesowicz, 2004).

Fig. 10 shows a typical screen with three windows: the main SCADA window and two virtual controllers – the single virtual PI and programmable virtual RW3 (similar to commercial Sipart DR24).

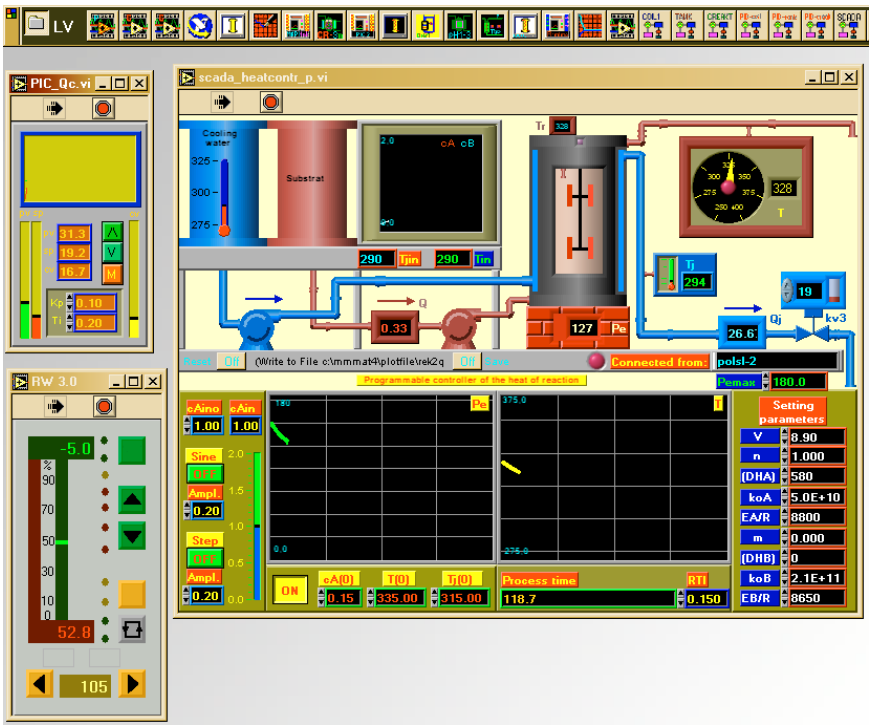


Fig. 4. Typical screen containing the SCADA HMI and two docking virtual controllers.

Summing up, it can be niticed that a new concept of easy performed control experiments on pilot plants with an application of virtual controllers evidently improves research and teaching capabilities and therefore becomes attractive and convenient. The remote data monitoring is possible for all interested in, as well as the view from five remotely controlled web-cams, whereas only authorised users can exert the control.

Methodology for remote experimenting on CSCI pilot plants

W. Nocoń, D. Choiński, M. Metzger

Modern industrial processes are becoming more and more demanding in terms of product quality and effectiveness of production or process operation. Those needs exert great pressure on the control algorithms applied to those processes. For those control algorithms to be effective a versatile tests need to be carried out, taking into consideration as many practical aspects of the processes as possible. Although simulation experiments are very useful for synthesis of control algorithms to be used in industry, experiments on the real-world processes should always be considered as the necessary and ultimate tests of those algorithms. For this reason, utilization of the experimental pilot-plants should be considered. Although experiments carried out on the pilot-plants will most probably be safe, those pilot-plants are not inexpensive. To tackle this problem, sharing the existing experimental pilot-plants through the Internet should be considered.

A methodology of a web-based control and monitoring of the experimental pilot-plants is described. This methodology is based on the National Instruments (NI) LabVIEW environment. This environment was chosen because all of the experimental pilot-plants built and operated at the Control Systems and Control Instrumentation Group (Institute of Automatic Control) are equipped with NI's FieldPoint FP-20XX or cFP20XX series controllers that are easily and conveniently programmed using LabVIEW. The presented methodology may easily be used to provide remote access to any of the experimental pilot-plants at the CSCI. A different approach to the experimental pilot-plants remote access has been presented above.

Remote operations

The functional diagram of the remote access to the experimental pilot-plant is presented in Fig. 1. The server side applications are responsible for communicating directly with the pilot-plant, executing the appropriate control program and retrieving data from the pilot-plant for viewing purposes. The Sequencing Controller (VI) is the backbone of the server side control software, since it communicates both with the I/O Server and with the client side control applications [III.33, III.34].

Remote control

In order to create an effective means of remote access and to minimize the necessary programming work, an existing feature of the LabVIEW environment – the Remote Panel - is used. This feature does not require the LabVIEW environment to be installed on the client side (only the LabVIEW Run-Time Engine is required). Clients install the LabVIEW Run-Time Engine while at the server side computer an HTML file is created that includes an `<OBJECT>` and `<EMBED>` tag that references the VI to be viewed and controlled by the client. This tag contains a URL reference to a VI and information that directs the Web browser to pass the VI to the LabVIEW browser plug-in. Clients navigate to the Web Server by entering the Web address of the Web Server in the address or URL field. The plug-in displays the front panel in the Web browser window

and communicates with the Web Server so the client can interact with the remote front panel. Hence the Remote Panel capability provides an easy and convenient access to the Sequencing Controller run on the server side. This enables the client to select the appropriate program, supervise its execution and even manipulate the program by changing program parameters. To provide security of those operations, only the clients with the trusted IP addresses are allowed to access the Remote Panel of the Sequencing Controller.

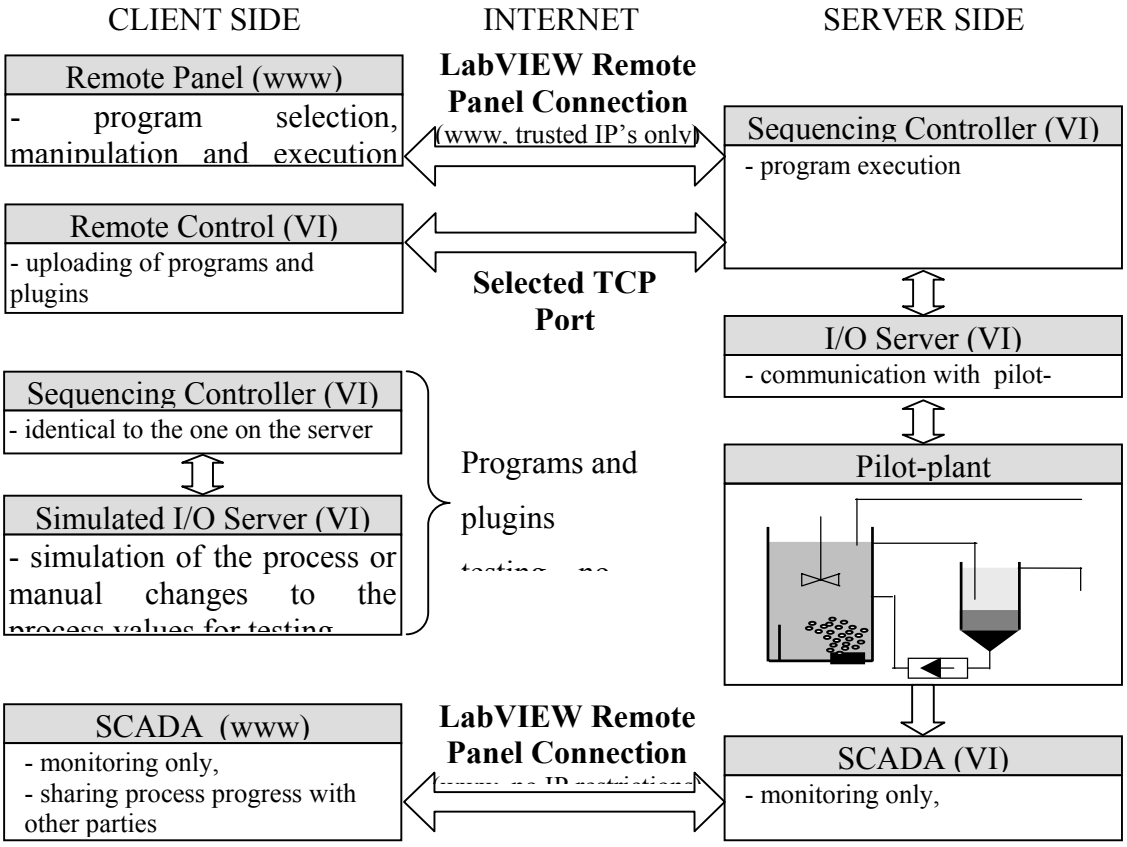


Fig. 1. Functional diagram of the remote access to the experimental pilot-plants.

The Remote Panel capability does not however enable the client to upload programs and plugins to the server nor to download the results from the server. For this purpose, a Remote Control (VI) is provided, that enables the uploading and downloading operations to be performed. The Remote Control application communicates directly with the Sequencing Controller using a selected TCP port. To provide security of this connection, the secure shell (SHH) is used [III.39]. Although the client and the server must specify the TCP port to use for this connection, the SSH uses port 22 as a secure link over the Internet.

Remote Monitoring

The server side of the presented methodology provides a possibility of viewing the pilot-plant operations by clients not authorized to make changes to control variables or program execution. A separate VI (SCADA) reads and presents all the measurements and controls from the pilot-plant. This VI may also be accessed remotely using the

LabVIEW Remote Panel connection, but in this case, usually no IP restrictions are imposed. An example of a remote SCADA application accessed using w web-browser is presented in Figure 2.

Fig. 2. Remote SCADA panel accessed through a web-browser.

The presented methodology serves as a backbone of the future LabVIEW-based remote access systems for the experimental pilot-plants at the Control Systems and Control Equipment Group. Because the presented methodology employs a few different mechanisms of accessing the pilot-plants, it is flexible and may be adapted to different needs and purposes. The control algorithms to be transmitted to the remote pilot-plants are programmed using the LabVIEW environment, thus making the remote access even more convenient.

Mathematical modelling of distributed feed in continuous sedimentation

W. Nocoń

Sedimentation is one of the most widely used processes for separation of solid particles from water in chemical and mineral industries as well as in wastewater treatment. Most of the continuous sedimentation models are based on the theory introduced by Kynch, according to which the settling velocity of solids particles depends only on the local suspended solids concentration. The process is described by a scalar conservation law in the form of a partial differential equation. Concentration discontinuities are present in this model and it is difficult to classify the steady-state solutions for changing feed flux values (different values of feed flow and feed concentration). Those discontinuities are introduced by the point source at the feed of solids and by the two outlets (top and bottom) of the settler.

A new method of modelling the feed section of the continuous sedimentation process is proposed. It takes into account the fact that the material entering the settler is distributed over a set of layers in the feed zone. In a one-dimensional modelling of sedimentation process it is assumed that the suspended solids concentration is only a function of depth and time. It is reasonable to expect that in the clarification and thickening zones this assumption will be met. However, that is not the case in the feed zone, where a significant horizontal flux of suspended solids exists.

What makes the proposed model distinct form the previous one-dimensional models presented in literature (point-source models, Figure 1b) is that the feed zone in not a lumped-parameter system. Instead, the feed zone of the continuous sedimentation process is in itself represented as a distributed parameter model (distributed-source model, Figure 1c). In addition, depth of the feed zone is not dependent on the space discretisation step.

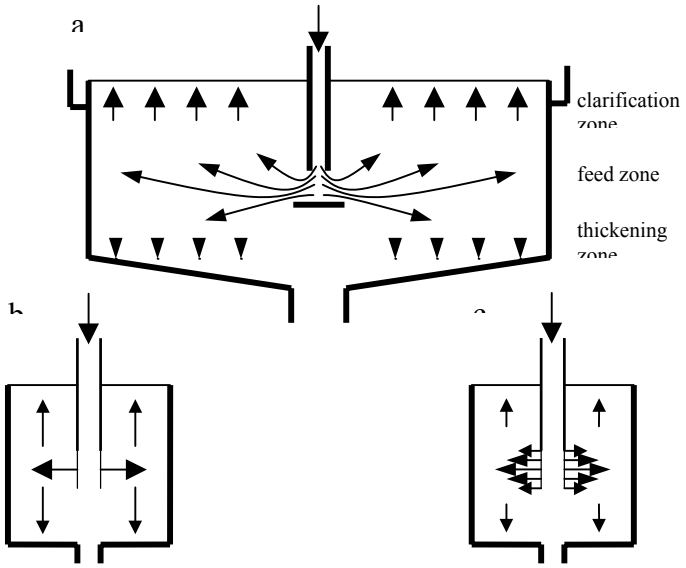


Fig.1. The general flow pattern in a real continuous sedimentation process (a) compared with the classical point-source 1D model (b) and the proposed distributed source 1D model (c).

The proposed model of distributed feed zone in the continuous sedimentation is based on the following postulates:

- **Imperfect mixing -** it is assumed that the feed zone does not consist of only one layer with perfect mixing. Instead, a set of layers is included in the feed zone and imperfect mixing is assumed between those layers,
- **Distribution function -** The amount of material entering each layer is not the same for every layer. A distribution function $f_d(r)$ (Fig. 2) is incorporated. This function distributes the material entering the settler over the layers in the feed zone,
- **Bulk flux zones -** The third postulate is based on the basic assumption that the flow into the settler equals the sum of underflow and overflow. Since, in the proposed model the feed zone consists of many layers, one particular layer has to be chosen to represent the boundary between the downward and upward bulk flux zones (Fig. 2). This is performed by a proper integration of the distribution function.

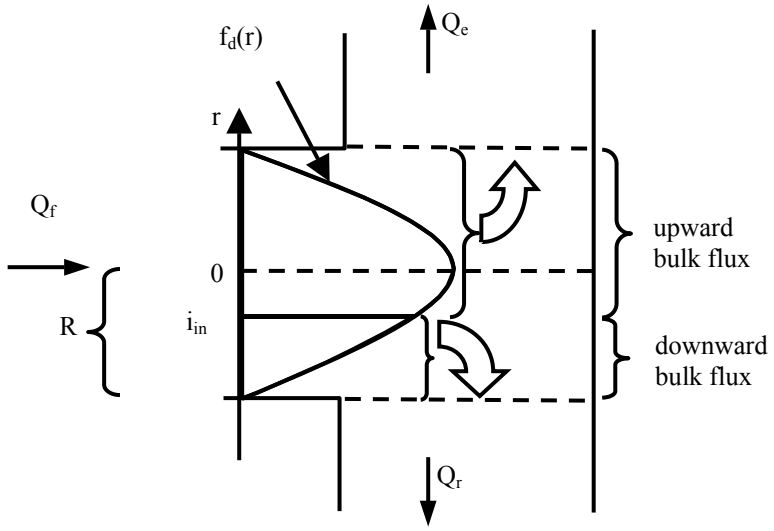


Fig. 2. Illustration of the proposed feed zone model.

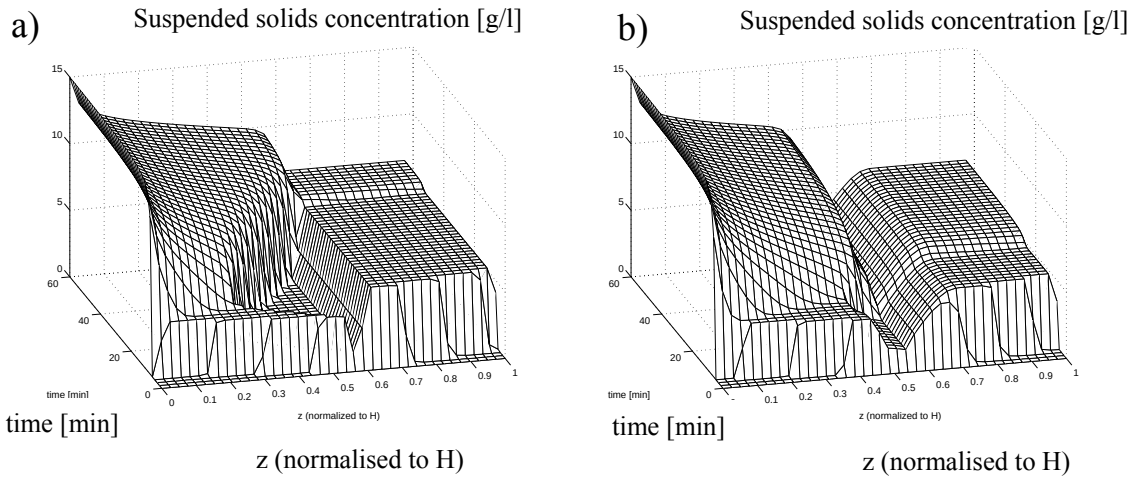


Fig. 3. Q_f=500[cm^3/min]; Q_r=50[cm^3/min]; X_f=6 [g/l]; a) feed zone with 1 layer; b) feed zone with 21 layers.

Figure 3 presents simulation results for the model with one feed zone layer (a) and 21 feed zone layers (b). The distributed feed model is thus compared with the standard point source model. In can be observed that the steady state values of X_r and X_e are identical for both models. The traditional models are considered accurate enough for predicting the general behaviour of the continuous settler. However, the dynamics of the settler and the steady state concentration distributions in the settler are different. As expected, the greatest differences are within the feed zone. In the traditional model a discontinuity of concentration is present (Figure 3a) which is eliminated in the proposed distributed source model (Figure 3b).

MEASUREMENT SYSTEM GROUP

RESEARCH ACTIVITIES

The research activities of the Measurement System Group are concentrating in the following main topics:

- Theory of Physical and Technical Measurement,
- Modelling of Measurement Signals and Systems,
- Principles of Industrial Measurement for Control Applications,
- Sensors and Sensor Interfaces,
- Methods of Calibration of Sensors and Measurement Instruments,
- Electrical Apparatus for Potentially Explosive Atmospheres; Intrinsically Safe Systems,
- Reliability.

Research on theory of physical and technical measurement
Fundamentals of Measurement

J. Piotrowski

1. Basis terms,
2. Measuring quantities and signals,
3. Transducer and instrument characteristics,
4. Measuring procedures and errors analysis,
5. Transducers and instruments for measuring of electrical quantities,
6. Sensors of non-electrical quantities,
7. Measurement systems.

Research on electrical apparatus for potentially explosive atmospheres; intrinsically safe apparatus and systems; sensors; reliability; functional safety

J. Frączek

The research problems of sensors (intelligent sensors, transducers and transmitters), apparatus and systems designing, including optical equipment (the measuring systems using laser and fibre optics), when they are destined for using in potentially explosive atmospheres. The main topics of these problems concern:

1. Sources of explosion hazards,
2. Characteristic parameters of intrinsic safety,
3. Classifications of apparatus and locations, grouping of gases, vapours, dusts and fibres,
4. Spark test apparatus,
5. Testing the intrinsically safe conditions,
6. Connecting lines in intrinsically safe systems,
7. Problems of reliability in intrinsically safe systems,
8. Reliability models of intrinsically safe systems and safety factors,
9. Functional safety,
10. Designing of intrinsically safe apparatus and systems,
11. Intensive sources of light in potentially explosive atmospheres,
12. Adoption of European Directives (ATEX 100A and ATEX 137) and Harmonized Standards in Poland, concerning apparatus and systems for potentially explosive atmospheres.

Research on industrial measurements; mathematical modelling of flowmeter sensors, flow measurement, radiation measurement, fundamentals of measurements

S. Waluś

1. Mathematical modelling of flowmeter primary devices,
2. Metrological optimisation of sampling flowmeters,
3. Construction of ultrasonic flowmeters and averaging impact tubes,
4. Measurement of flow-rate in closed conduits and in open channels,
5. Didactic of metrology,
6. Fundamentals of measurements,
7. Radiation measurements and radiological protections,

Research on the system of monitoring of climatic parameters in measuring laboratories

J. Żelezik

A purpose of the system is monitoring climatic parameters: the temperature, humidity and the barometric pressure in measuring laboratories. Monitoring is necessary at every examinations of the measuring apparatus, calibration of measuring instruments, he is

required in particular in accredited measuring laboratories. The whole system was designed and realized from grounds in the Measurements System Group. He is based on smart measuring transmitters – termohigrobarometers THB and termohigrometers TH with the serial interface and the MODBUS protocol. The multiparameter transmitters are realizing functions:

- Measurements of signals from sensors of the temperature, humidity and the absolute pressure,
- Filtration; averaging measurements,
- measurand reproducing (also the temperature errors compensation and the correction of the nonlinearity error),
- two-way remote communication through the serial interface (RS485 and/or RS232C) according to the MODBUS protocol,
- the remote configuration;
- displaying results of the measurement on the local LCD display.

On Fig. 1 appearance of one of transmitters installed in laboratories was shown. All transmitters were before installing calibrated out. The most important metrological characteristics are given in the table 1.

Fig. 1. Appearance of the transmitter installed in the laboratory.

Table 1

Parametr	Barometer pressure	temperature	Humidity
Range	750 - 1150 hPa	(-40) -10 - 70 °C	0 - 100 %
Accuracy	0.3 hPa	0.3 °C	2 - 4 %
Resolution	0.1 hPa	0.1 °C	0.1%

A standard of the RS-485 interface was chosen as the physical layer of the network what is a most simple and not very expensive and at the same time fulfilling the

requirements solution regarding the range, speed of the broadcast etc. The microcomputer fitted with the converter is a system controller. Software was realized with LabView. The realized measuring network includes laboratories located on two floors in the A building of the AEiI department and one measuring point outside the building as it was shown on Fig. 2.

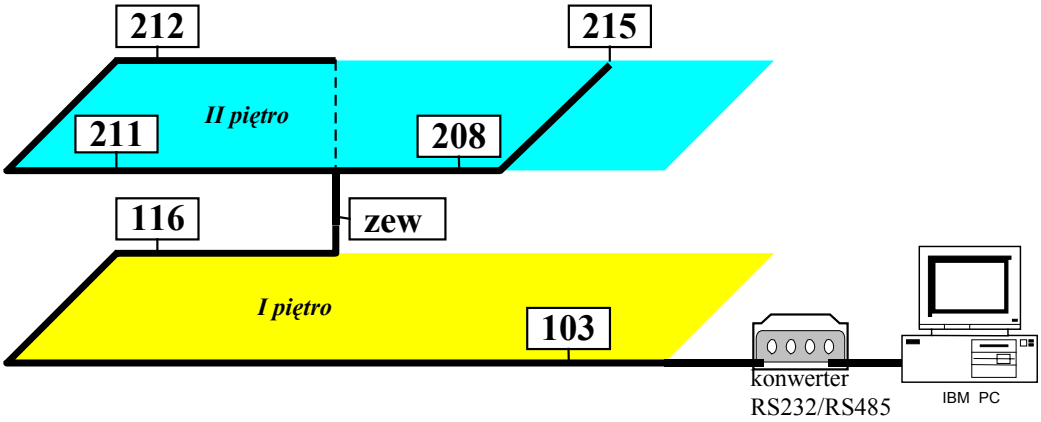


Fig. 2. Arranging elements of the system of monitoring in the building AEiI.

The system is working in the continuous way. Results of measurements in laboratories and outside (the local and reduced barometric pressure, the temperature, relative humidity and the dew point) are presented in the numeric and graphical form on the monitor of the system controller, as well as on the internet site: www.pomiary.polsl.gliwice.pl. The user is able to look timing diagrams of measurements through in the arbitrary, chosen horizon of the observation as it was shown for instance on Fig.3 and 4.

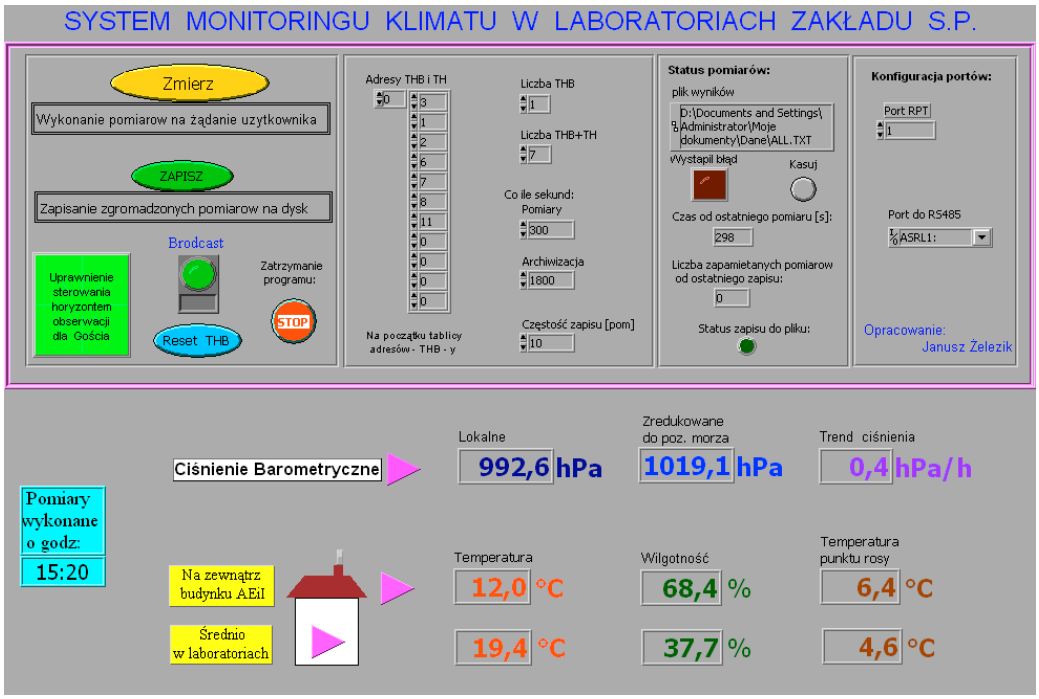


Fig. 3. Configuration and data presentation panel.

Fig. 4. Graphical presentation of results of measurements

Research on Least Median of Squares Method in Measuring Instruments Calibration

J. Piotrowski, D. Buchczik

Regression analysis is a fundamental statistical tool commonly applied in a calibration of measuring instruments and systems. The last squares (LS) method is generally used because of tradition and computational simplicity. However there exists danger of occurrence of outliers, which may totally spoil LS analysis. To avoid this problem statistical techniques called robust regression have been developed. One of the most advanced and promising robust procedure is the least median of squares (LMS) method. The LMS is based on the minimization of the median of the squared residuals, in contrast to the LS method, where the sum of the squared residuals is minimized. Due to the computational complexity of the LMS some statistical properties of the method have not been determined yet. The research is focused on the variance of the LMS regression coefficients. Procedures of a priori and a posteriori estimation of the variance of the LMS coefficients have been developed. The problem of the computation of the LMS regression coefficients is also under investigation. There have been examined computational algorithms based on PROGRESS, a genetic algorithm, a simplex method and two-stage procedures. The obtained results are the basics of the Ph.D. dissertation.

Research on modelling of measurement signals and systems Wavelet analysis in signal processing

J. Piotrowski, R. Wyżgolik

A multi-resolution analysis (a wavelet analysis method) is applied to detect the first arrival of a P wave in seismic signals from coal mines. The main aim is to use this method to low amplitude, therefore noisy seismic signals. The property is used, that the first arrival of the P phase can appear in the wavelet coefficients across several scales. First the decomposition procedure is performed, then if required, the noise reducing methods can be applied (based also on wavelet analysis). At the end, the product absolute value of chosen details is observed. The jump of the details is clearly visible at the moment of the P phase arrival (Fig.2 as an example).

The discrete wavelet approach to low-amplitude seismic signals from coal-mines gives us the possibility of the P phase arrival detection. For such a low-amplitude signals this method is more reliable than currently used in coal-mine tremor stations. However due to very no stationary character of these signals it is difficult to give one general solution.

The computer software named **Seismic signal analyser.vi** has been developed for P phase time arrival detection, using wavelet multi-resolution analysis. The software is mainly designed to process seismic signals from coal mines (it requires special file format). But any other signal in ASCII format can be also analyzed. The front panel of the **Seismic signal anlyser.vi** is presented in Fig.1. It enables signal analysis using typical denosing methods and parameters, and the three types of wavelets:

- Daubechies of order 1 (Haar wavelet) up to 22,
- Symlet and Coiflet.

The abrupt changes detection procedure is call by pressing DETECT button. The **P phase detector.vi** front panel is presented in Fig.2.

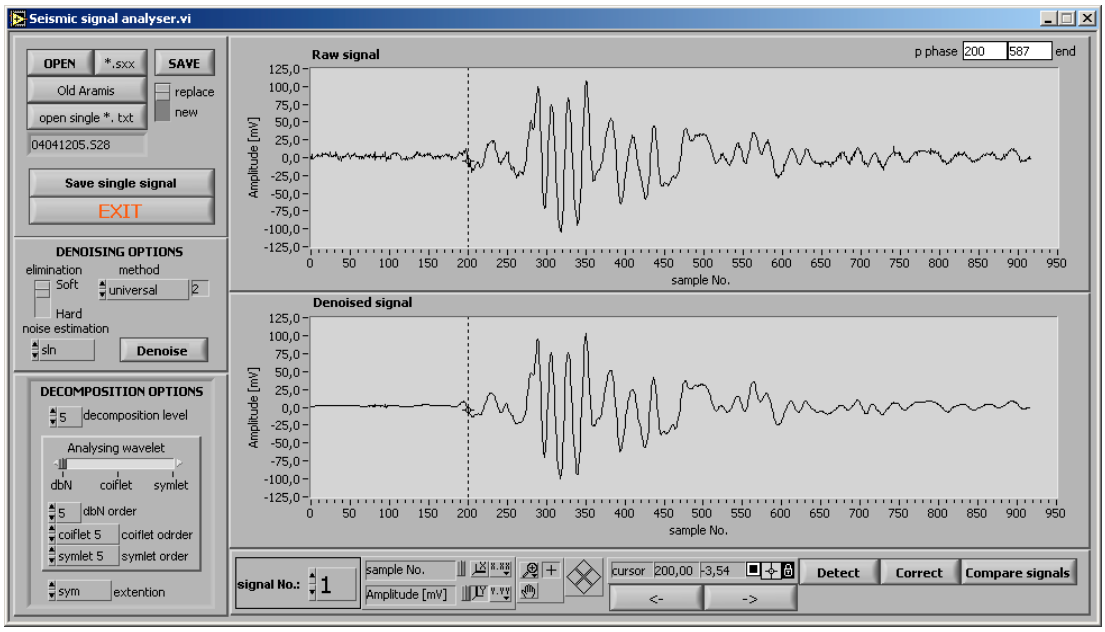


Fig. 1. Front panel of the **Seismic signal analyzer.vi.**

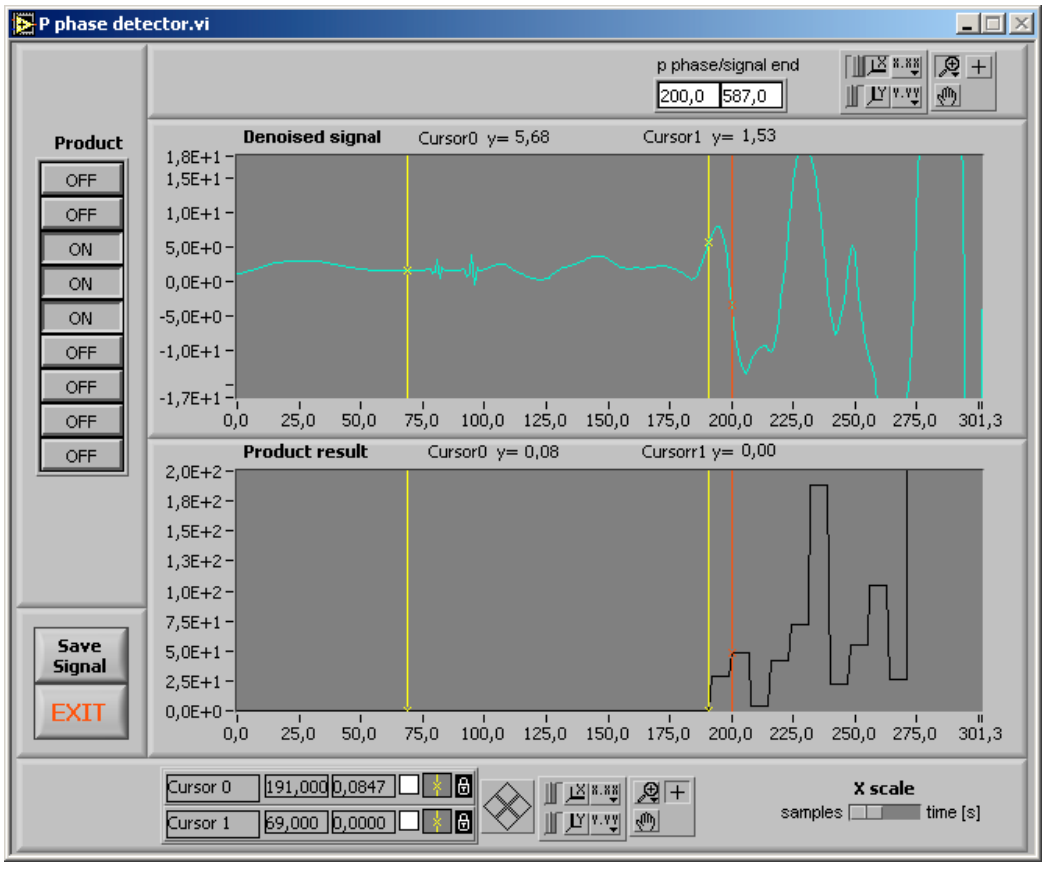


Fig. 2. Front panel of the **P phase detector.vi.**

Research on principles of industrial measurement for control applications
Measurement of proprieties of Ion Selective Electrodes for multi-component measurements purpose

J. Frączek, A. Kozyra

The application of chemo-metrics in multi-component analysis is rapidly expanding area of analytical chemistry. Ion Selective Electrodes (ISEs) have found use especially for the direct determination of ionic activity in biological samples (food, blood, serum, urine) and determination of the water quality. The potential of the ISE depends on chemical activities of particular ions in a solution.

A typical measurement, using the ISE, needs a specially prepared sample to eliminate interference of other ions on which this electrode also reacts. Recently, more selective electrodes can be used to determine ion activities of multi-ion samples. In multi-component measurements (MCM) an array of multiple electrodes is applied. Each electrode reacts on many other ions in solution. The relationship is described by an empirical Nikolsky-Eisenmann equation (Fig.2b). The potential of an ion selective indicator electrode is measured against a reference electrode, the potential of which should remain constant. When we know the parameters of electrodes, we can estimate the amount of ions in the sample. But before the measurement, the calibration of electrodes array is necessary, because the parameters of electrodes could change.

The adequate accuracy is required in the measurements, number of measurements and complicated procedure of calibration requires a special stand for the MCM (Fig.1).

a) b)

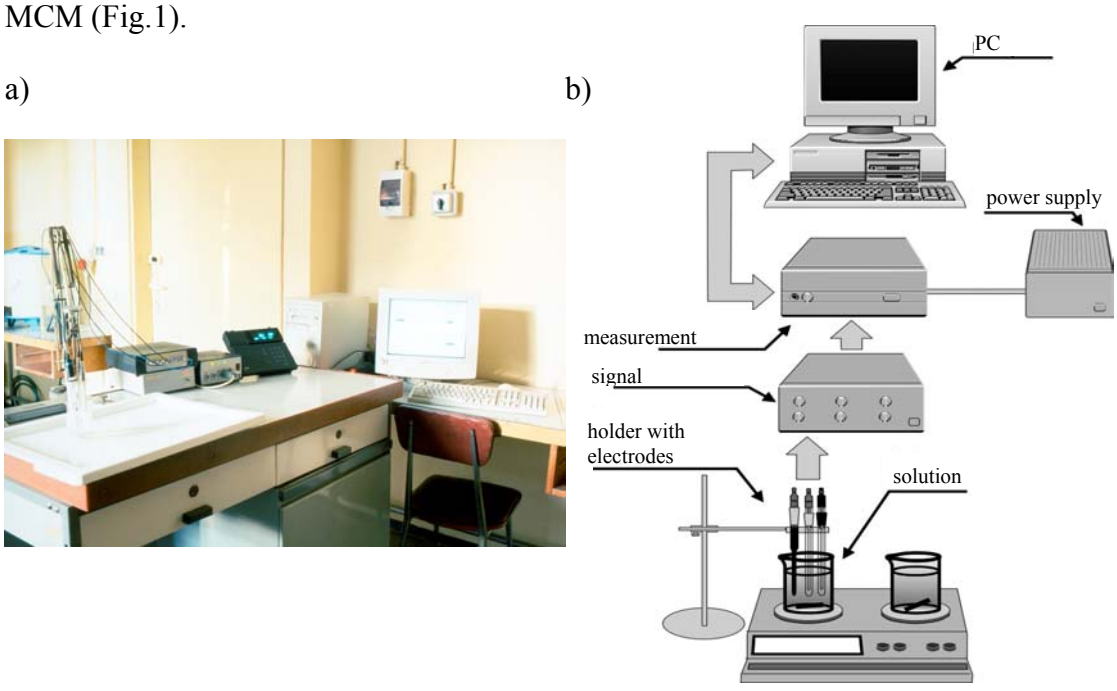


Fig. 1 The stand for multi-component ion-selective measurements:
a) photo, b) schematic draw.

The stand consist of the ISEs and a temperature sensor, a signal conditioner, 16-bit A/D with microprocessor based communication module. All data are acquired by computer. A special calibration and ion activity multi-component measurements procedures are implemented. Typical electrode characteristic is shown on Fig. 2a. Each electrode is

characterised by different parameters like: slope, standard potential, limit of detection and selectivity coefficients. It is very important to determine those parameters with proper accuracy. There are many different factors which influence electrode potential such as temperature, electrode potential drift and contamination of the electrode membrane. It is very important to recalibrate them with the proper frequency. For this purpose a set of reference solutions must be prepared, in which the activity values of individual ions, have to cover the whole range of activities assumed to appear in the real solution.

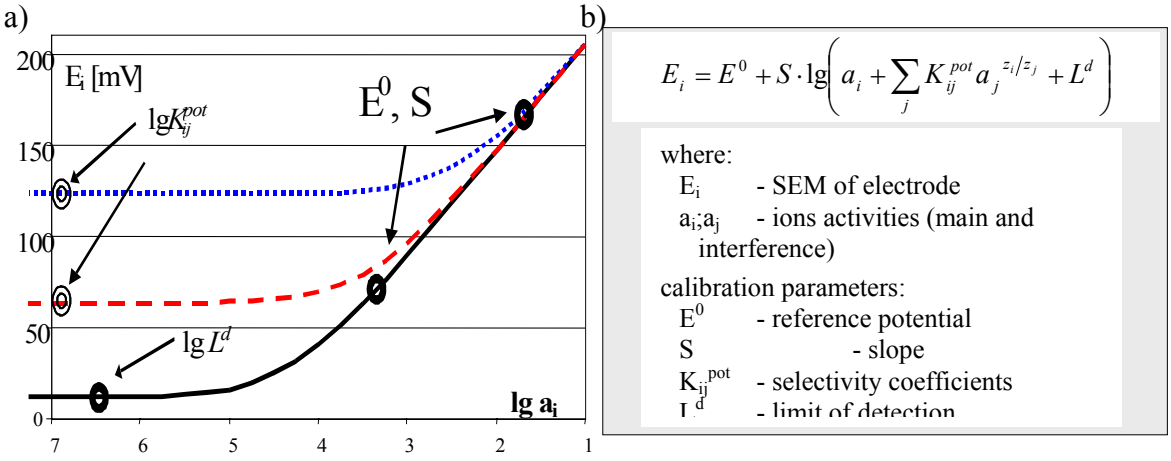


Fig. 2. a) Characteristic of Na^+ electrode potential in pure NaCl solution (black solid line) and in presence of interfering ion (NH_4^+ pX=0.7 or K^+ pX=2 dashed red and dotted blue line respectively). There are examples of calibration points used for calibration. b) ISE electrode model used for measurement analysis.

In our investigations new calibration procedures are developed and tested to find simpler and more suitable procedures for MCM measurements. Procedures where different ISEs (electrodes selective on different ions) are calibrated simultaneously in the same calibration solution.

Evaluated parameters of electrodes are used for determination of ion activities in many aqueous solutions (mineral, tap water, dissolved ground samples, dissolved medicine pills, tooth-paste etc). Not only activity but also uncertainty of measurements had to be evaluated – it is very important because in the same situation the direct MCM are impossible due to masking proprieties of interference ions.

Research on Dynamic Behaviour of the Ion-Selective Electrodes

J. Frączek, A. Wiora

Research on a dynamic of ion-selective electrodes (ISE) permits a description of their behaviour during measurements. One of parameters of the ion-selective electrodes is the response time t_{90}, which is defined as a time, within the electrode achieve 90% of the response signal. Another one is the delay time t_0. The overall response time is affected by a series of factors dependent either on the electrode (a type of membrane and electrode structure) or on external factors (temperature and flow of the sample, time constant of the measuring instruments).

Because of the complexity of phenomena, which occur in the measuring systems and many factors which influence on the dynamic response of the electrode, the following conditions should be fulfilled:

- the influences of distractions should be eliminated or minimised,
- the flow of sample should be constant,
- the step change of sample activity on the membrane should be ensured.

Research on the dynamic of the ion-selective electrodes are performed by using the measuring cell (Fig.1). The measuring cell is designed for dynamic measurements which use one or two electrodes at the same time. It permits the step change of two mixtures having different activity. The results of measurements are registered by using JPomiar software, which take place in a Measurement System Laboratory. Received real response time of ISEs is approximated using different dynamic models and is compared with t_{90}. The dispersion of issues is less then 7% for t_{90} for measurements made at the same conditions.

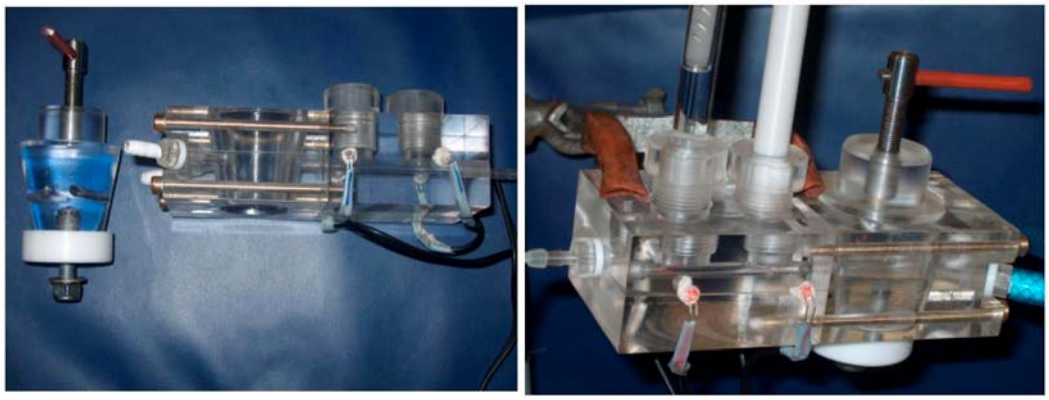


Fig. 1. The measuring cell for research on a dynamic of ISE.

Research onComparison and Assessment of Models used in the Ion-Selective Measurements

J. Frączek, J. Wiora

The knowledge of phenomena, which take place in automatic controlled plants is very important. Therefore, almost all of the automatic controlled systems possess at least one sensor which transforms a non-electrical quantity to an electrical one. Very often such a sensor may be a very simple one, however in this situation its accuracy is low. To improve the feature specialized converters are added, very often supported by a microprocessor based unit. The microprocessor is needed because of an increase in the complexity of the mathematical model of physical-chemical phenomena with the increase in the accuracy or in the measurement uncertainty required.

Nowadays, electronic devices (such as measurement amplifiers, analog to digital converters, microprocessor systems) are still very rapidly developed. On the other hand, progress in physical-chemical sciences allows the application of improved mathematical models. As a consequence, it leads to an enhancement of the measurement quality.

Ion-selective measurements made by using ion-selective electrodes, which are a part of the measurements of a physical-chemical phenomena, allow us to determine the chemical activity of certain ion present in a water solution by measuring the voltage

between two electrodes. Due to some properties this method cannot be replaced with any another one. The main properties are:

- Direct measurement of an ion activity in given solution,
- Possibility of making the *in vivo* measurement,
- Possibility of a continuous measurement.

The research concentrates on the ordering of the already known static models of the phenomena which take place during the measurement by using ion-selective electrodes. Great amount of parameters influence on the result, *i.e.* the limit of detection, the Nerstian slope, the potentiometric selectivity coefficients, the activity coefficient, the liquid-junction potential and other. However, if the maximum accuracy is assumed, it is not necessary to take into consideration all of these parameters. Otherwise the model would become unnecessarily complex.

The research consists in the calculation and simulation of the value of the measured quantity *vs.* the changes in influence parameters. In this way the final accuracy is estimated. In the next step the application criterion of models are formed. The nature of studied phenomena is strong nonlinear, hence there are many difficulties. One of them can be the determination of the calibration coefficients, which can be obtained either by the iterated numerical solving of the equations or by the application of the artificial neural network.

The studied theories are verified by experiments. It is made in the laboratory of the Measurement System Group. The experiments base on the ion-selective electrodes sensitive on Na^+, K^+ or Ca^{++} ions. The results obtained are required to write the Ph.D. dissertation.

Research on the use of fuzzy logic to decisions making at monitoring of coal mine's atmosphere

J.Frączek, T.Grychowski

Led investigations have use of fuzzy logic and her mechanisms of inference to aid of set at monitoring of mine's atmosphere on aim. Use of fuzzy expert system has improvement of safety of work of down ship's company for assignment. Expert system is created change of warehouse of mine's air in aim of rise of reliability of detecting and identification of caused threat. Algorithm of processing of measure signals uses early defined bases of knowledge from expert and created in support about knowledge and mining regulations. Studied of applied mechanism of inferences and buildings of membership functions are onto decision result.

Into composition of controls system of mine's atmosphere they come in controlling device content of oxygen-O_2, methane-CH_4, carbon dioxide-CO_2, carbon monoxide-CO in the air as well as temperature and relative humidity of air. Controlled is also direction and speed of airs flow.

The computer program for automatic decisions making are created in LabVIEW from National Instrument with used the Fuzzy Logic Controller Design Tool. Computer data to simulation are capture from existing control systems of mine's atmosphere. Investigations are executed also on laboratory position into which warehouse comes in steering computer, measure route, measure permitting devices onto remote registration of physical and chemical airs parameters. System permits onto detecting of emergency

states as well as processing of measure signals makes possible in aim of qualification make up threats. The application is still under development.

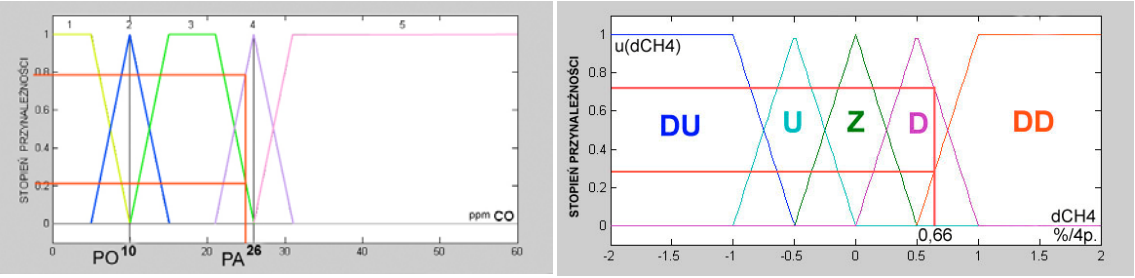


Fig 1. Examples of membership functions for concentration of carbon monoxide (example of fuzzy alarm thresholds)- on the left side, as well as fuzzy classes for change of methane concentration in time - on the right side.

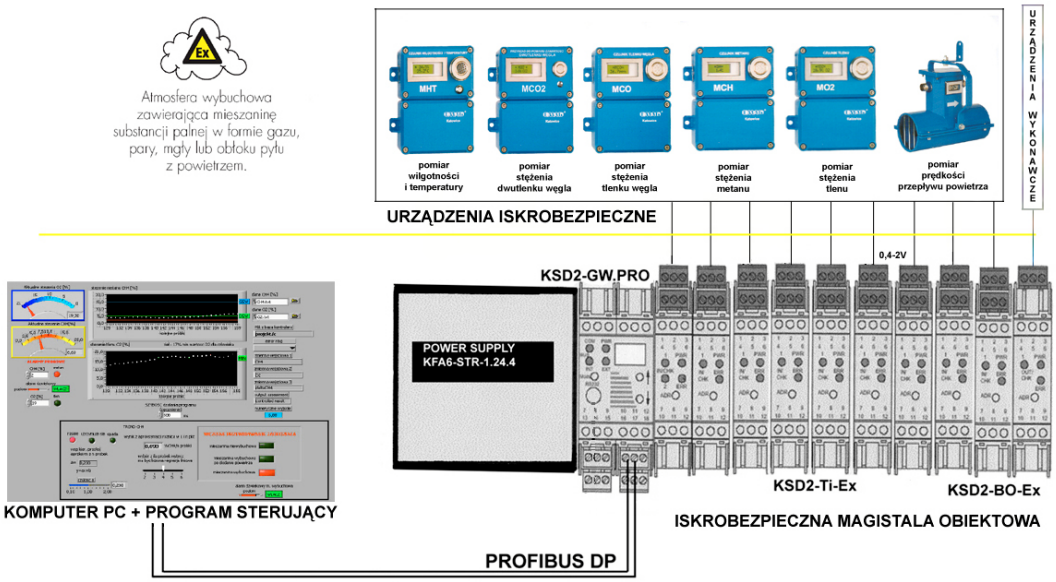


Fig 2. The stand for multiparameter gas measurements. Diagram of laboratory's position.

Research on methods for three dimensional measurement data conversion

K. Wojciechowski, S. Budzan

The 3D analysis methods are applied often to eliminate the groups of bad points - noise data, segmentation and filtration – smoothing, also classification objects in cloud of points.

The 3D data are captured by means of Laser Scanner - Digital Light Projection or ALS (Airborne Laser Scanner) Systems. The elimination of bad points is commonly realized by manual selection of the groups of bad points. However, several methods are based on semi-automatic 3D grouping - based on calculation of Hausdorff distances.

The Segmentation cloud of points is realized by combining growing methods and 3D Hough Transform (HT). Thereupon object in 3D Data are classified, e.g. planar, elliptical or more complicated surfaces.

The Hough Transform was first introduced as a method of detecting patterns of points in image data. With reference to a specific pattern model, the Hough transform examines each point and finds all possible model parameters that agree with it. By collecting all such parameters in a properly defined parameter space (Hough space) we can determine data patterns that comply with the reference model through cluster identification in the Hough space. In practice, the HT converts a complex pattern detection problem in the image space into a more manageable peak detection problem in the parameter space.

Currently, the main destination of the research is to analyse of the algorithms for filtering and classification the laser scanner data, also to make the software implementation.

ADDITIONAL INFORMATIONS

The members of MS Group are involved in several science and research societies:

J. Frączek:

- Commission of Metrology of Katowice Branch of Polish Academy of Science (chairman),
- Polish Society of Sensors Technology (member),
- Editorial Board of national journal: Mechanizacja i Automatyzacja Górnictwa (member),
- Editorial Board of national journal: Elektronika(member),
- Polish Committee on Automation of Mines and Quarries (PCAMC) (member).
- National Elaboration Group for the Polish Edition of the Directive ATEX 100A (member),
- Polish Standardization Committee, Technical Commission No 64: Electrical apparatus for potentially explosive atmospheres (member),
- The Quality Assurance Council of the Certifying Body at the Central Mining Institute (chairmen),
- The Quality Assurance Council at the RW TÜW Poland plc Katowice (chairman),
- Chairmen of the National Conferences: 1). VII Seminary ZONA'2003 "Hazard in energetic objects and industrial plants - means to avoide them" 2). VIII Conf. – ZONA'2004 – "Safety of objects in the fire zones and in the potentially explosive atmospheres". 3). ENERGO-EKO-TECH'2003 Conf. on "Electrical devices and installations in potentially explosive atmospheres".

S. Waluś:

- Commission of Metrology of Katowice Branch of Polish Academy of Sciences (secretary),
- Polish Society of Sensors Technology (member),
- Polish Society of Metrology (member).

J. Żelezik, R. Wyżgolik: W. Ilewicz

– Commission of Metrology of Katowice Branch of Polish Academy of Sciences (members).

ROBOTICS AND DISCRETE EVENTS AUTOMATION GROUP

The research activities of the RDEA Group concentrate on:
- computer integrated manufacturing,
- robot control systems,
- colour image processing.

COMPUTER INTEGRATED MANUFACTURING

Follow-up production control

M. Zaborowski

The main purpose of an enterprise is to satisfy all customer requirements that do not exceed capacity of the production system. Therefore every production planning and control system may be considered as a system, which function is to adapt the assortment and the rate of production to currently accepted customer orders. The conformability of production and customer orders may never be ideal. However, it is possible to construct a production management system in which the backlogs between the actual demand and production are under control, owing to feedback loops from material flows to corresponding decisions making procedures. Using backlog components as the sources of feedback signals in the multilevel production control system is the main idea of the follow-up production control.

The follow-up production control system is a hierarchical system (fig.1). It has three functional layers:
- coordination of planned production orders and their distribution among work cells and their preparedness variants,
- follow-up scheduling, which is applied to each work cell separately and independently,
- material flow synchronization inside every work cell.

For each layer the backlogs between their leading variables and decision variables are currently calculated and immediately applied to decision making procedures.

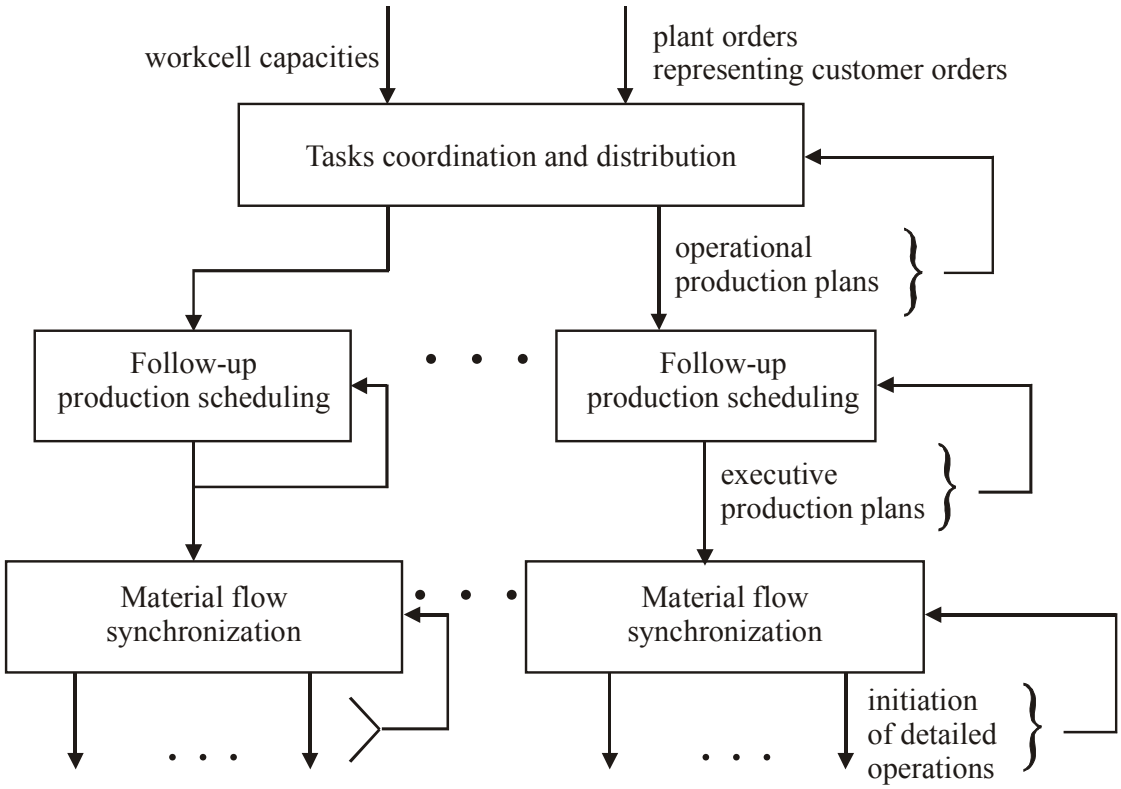


Fig.1. Functional structure of the follow-up production control system.

In a follow-up production control system every work cell is a production subsystem (production island) with concurrent manufacturing processes. For each such a process the operations, executed in workstations of its routing, are synchronized. The partitioned flow production line, which may be variously divided into partitions designated to concurrent processing different product, is an example of the work cell (fig.2). The particular case, without concurrent processes, is the ordinary flow production line. Another particular case of the work cell in a follow-up production control system is a single workstation. In every case the set of products, which may be manufactured by the cell, depends on the equipment installed in it. Such a set of products is named "preparedness variant" of the work cell. The variant with number zero corresponds to the idle time.

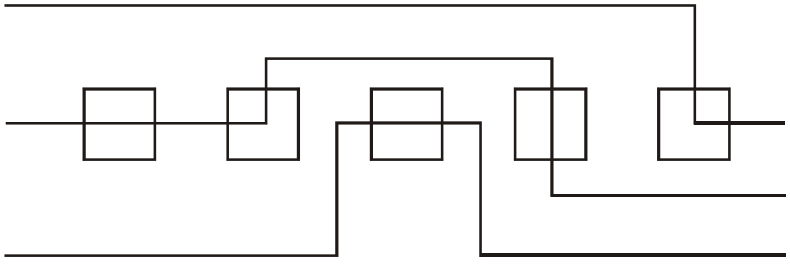


Fig.2. An example of routings in the flow production line with concurrent processing of different executive orders.

For a given work cell, after each period of work or idle time, the follow-up scheduling algorithm decides about the preparedness variant for the next period, as well as about length of this period. Thus, the next time when decision will be needed may be easily calculated. If the preparedness variant number is greater than zero, the algorithm gives lot-sizes of products corresponding to this variant. Parts of these lot-sizes, that fall to single executive planning periods belonging to a given work period, are executive plans. Their counterparts for operational planning periods, issued from the layer of planned orders coordination and distribution, are operational plans. Both, operational and executive plans are currently generated for consecutive planning periods (fig.3). In contradistinction to executive plans, the operational ones, concerning a given work cell, do not have to satisfy the condition of mutual exclusion of different preparedness variants.

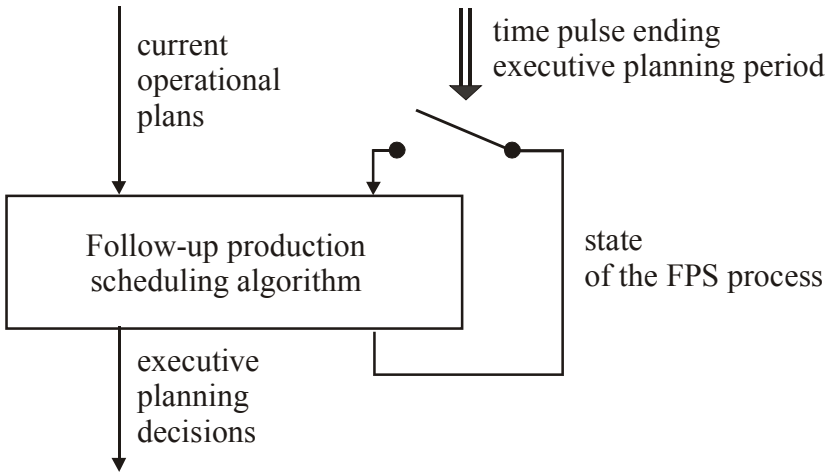


Fig.3. Application of the follow-up production scheduling to make current decision of the executive planning.

The algorithm has been named “follow-up scheduling” because it ensures that its backlogs, that is running totals of differences between material flow rates, calculated on the ground of operational and executive plans, are limited for infinite time horizon. In other words, for each work cell the follow-up control system, with operational plans as leading variables and executive plans as controlled variables, is stable. The main assumption of the stability theorem is that operational plans do not exceed capacity of the work cell which is the object of control.

Another quality of the follow-up scheduling algorithm is convergence of corresponding decision process. It means that if leading operational plans are constant or cyclic then following executive plans become cyclic after finite number of planning periods. The repetition period of these plans is the one of the algorithm parameters. The main assumption of the convergence theorem is the same as for stability. Convergence of current executive plans to cyclic schedules is important because repetitive production systems are usually designed to strictly cyclic work. Thus, after disturbances termination they should automatically pass on to the cyclic work mode.

Simulation researches of the follow-up scheduling algorithm

J. Krystek

An internet implementation of the follow-up scheduling algorithm was created. The application makes detailed researches of the algorithm operation. The researches concentrate on checking influence the various dispatch rules of production variants selection on duration transient state and properties cyclic schedule and defining influence these rules on the follow-up scheduling algorithm quality work.

Application „Algorytm Nadążnego Harmonogramowania Produkcji" in action can be at URL: http://nhp.f11.com.pl. seen.

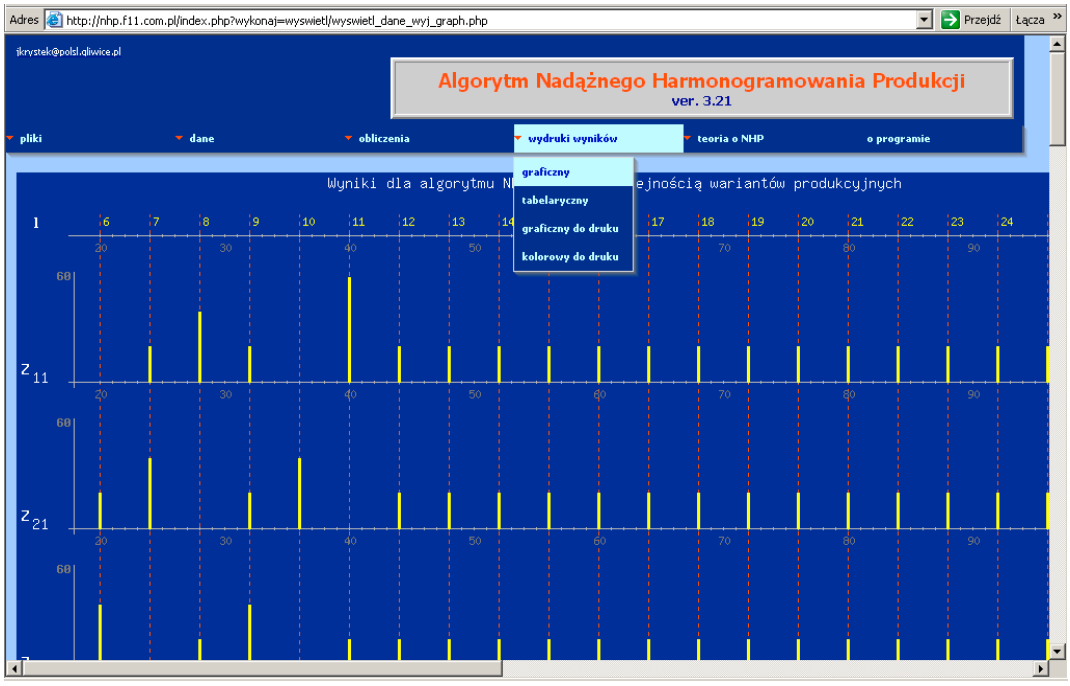


Fig. 1. Internet application.

Finite scheduling in the MRP II environment

M. Zaborowski

In the MRP II (Manufacturing Resource Planning) standard system all decisions are made by people. The most detailed ones are shop orders and shop tasks. Each shop order points out the product to manufacture, the routing of the manufacturing process, the due date and the order quantity. Shop tasks are specification of a given shop order and concern particular operations of the manufacturing process. So, shop orders and shop tasks give answers to the questions what, how, where, when and how much to manufacture.

Shop orders are conformable with planned production orders from the MRP (Material Requirements Planning) module which, in turn, are conformable with master production schedule (MPS), but all these decisions are made without taking into account capacity of the plant. Such decision procedure is called "infinite scheduling". Afterwards, shop orders are verified in the CRP (Capacity Requirements Planning)

module. If shop tasks exceed capacity of work centers allocated to them the planner modifies shop orders properly. If it is not sufficient another planners must modify planned orders and, perhaps, master production schedule.

The alternative of such standard decision making process is "finite scheduling" which gives, as the first solution, shop orders and tasks satisfying all capacity constraints. To enable finite scheduling the mathematical model of all constraints that are imposed on shop orders was created. The following constraints were introduced to the model:

- lead times between release times and due dates of shop orders,
- material requirements interdependecies for routings,
- multilevel bill of material structure,
- material balance equations,
- customer orders,
- purchase orders limits,
- relations between shop order and planned order quantities,
- relations between task quantities, tasks durations and work center load.

In MRP II environment all data and decisions are stored in relational databases. Thus, essential information is comprised in the mere occurence or lack of occurence of certain rows in data tables. Therefore the suggested mathematical model of MRP II system is the relational one. To decrease difficulties involved by complexity of data structure the original notation of Entity-Relationship Diagrams was proposed. It is similar to the Martin's notation of the "crow's feet" but it is considerably simplified, what is allowed in this case.

ERP system IFS Applications and the MRP II environment

M. Jagodziński

In the MRP II (Manufacturing Resource Planning) standard system all decisions are made by people. The most detailed ones are shop orders and shop tasks. Each shop order points out the product to manufacture, the routing of the manufacturing process, the due date and the order quantity. Shop tasks are specification of a given shop order and concern particular operations of the manufacturing process. So, shop orders and shop tasks give answers to the questions what, how, where, when and how much to manufacture.

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Integrated enterprise management systems, including IFS Applications, coordinate flow and analysis of information regarding full product life cycle in framework of integrated supply chain SCM, it means from design to production planning, production, controlling, supplying and service (fig. 1).

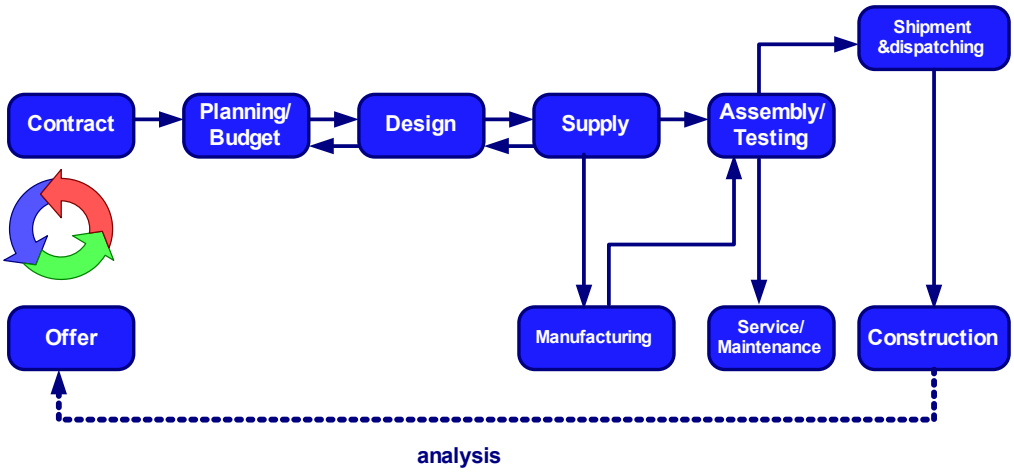


Fig.1. The product life cycle in IFS Applications system.

Assembly Line Balancing Problem

W. Grzechca

The line balancing problem is one of the most important problems of preliminary design stage for flow-line production systems. This problem was generally studied for assembly lines with a relatively simple structure (simple line, U-shaped line, parallel line, mixed line). For a given set of manufacturing operations and a given cycle time, the classical line balancing problem consists in assigning each operation to a workstation such that the number of workstations is minimized and precedence constraints are satisfied. The dual problem is minimization of the cycle time for a given number of workstations. A generalized line balancing problem consists of distributing operations among workstations while minimizing some criteria different than number of workstations (cost, productivity, reliability, maintainability, etc.) and taking into account some additional constraints. Many models for optimal line balancing are deterministic, the processing times are supposed to be fixed. Finally, production line balancing has usually several important criteria such as productivity, availability, investment costs, labor costs, utility costs, maintenance costs, etc. In this case, Pareto approach for multi-criteria optimization is a natural tool for dealing with various competing objectives of design problems. Other goal of investigations is comparing heuristic solutions, which are the only one available for most assembly line balancing problems. Also genetic algorithms are good tools in finding feasible solution of discussed problems.

Research on e-learning “Computer Aided Drawings and Fundamentals of Machine Design”

W. Sileikis

This research concentrates on „Assiniboine” model used for the creation of web-based courses. This model was based on the series of web pages as the ”backbone” from which other materials may be accessed. In the „Assiniboine” model, the basic unit is the

module. A course, is a collection of modules. A typical course would be composed of 15 or 20 modules.

The World Wide Web is an ideal environment for information publishers, but the WWW, in combination with other Internet tools such as Usenet newsgroups, e-mail, FTP and telnet, can be an interactive learning environment as well. The creative implementation of these tools makes the WWW an ideal environment for learning.

E-learning provides faster learning at reduced costs, increased access to learning, and clear accountability for all participants in the learning process. This model can be used in combination with traditional classroom-based courses for teaching of ”Computer Aided Drawings and Fundamentals of Machine Design”. An example of modules of this concept in action can be seen at learning portal „Zdalne nauczanie ZiPK” (fig. 1).

URL: http://pcws.zis.ia.polsl.gliwice.pl

URL: http://www.zis.ia.polsl.gliwice.pl/~vytautas

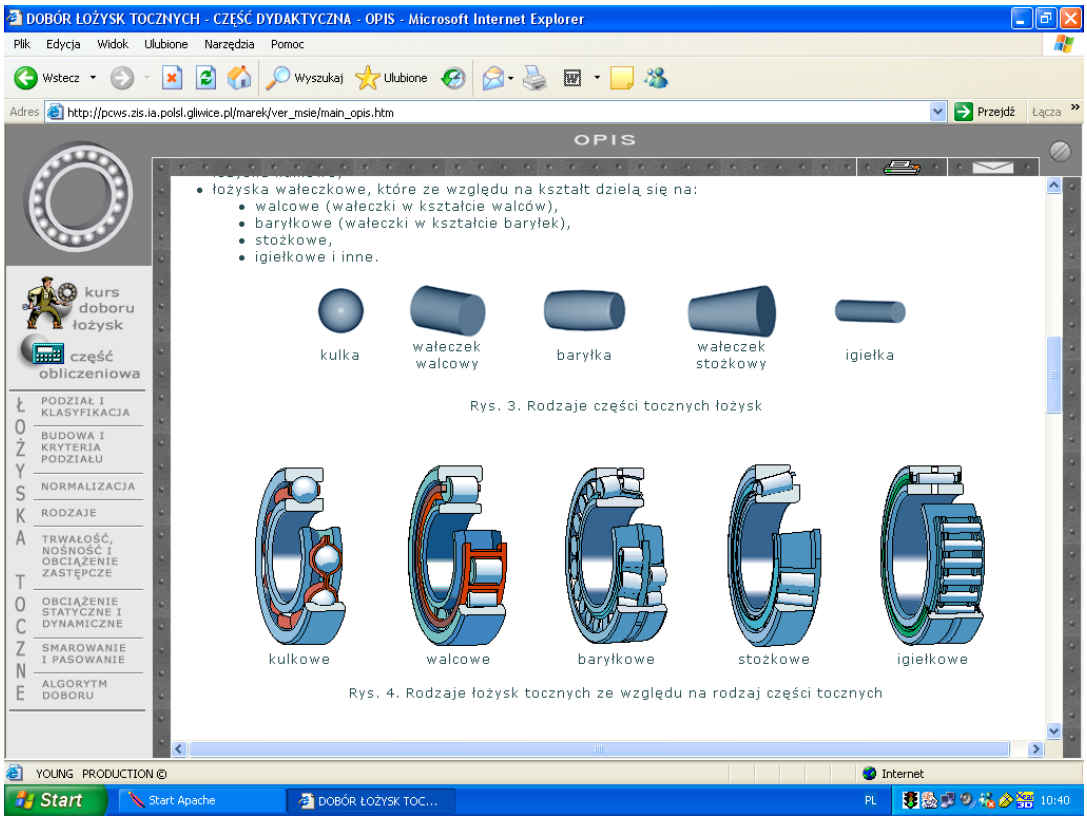


Fig. 1. E-learning module “Rolling bearings”.

ROBOT CONTROL SYSTEMS

Research on modelling, planning and simulation of robot manipulator movement

T. Szkodny

The fundamental problems of robotics are concentrating in following topics:

- modelling of robot manipulator movement,

- planning trajectories of manipulator,
- simulation robot movement and control,
- control of robots.

These problems are solving for robots located in laboratory of Robotics and Discrete Events Automation Group. Mathematical models of movements of these robots were developed. Based on these models, the motion planning algorithms for some manipulators were obtained. The description of motion planning algorithm designed for the IRb-6 manipulator is presented below.

The design of motion planning algorithms bases on formulas, which are solutions of an inverse problem of manipulator kinematics. The natural coordinates correspond to the reference trajectory of manipulation object described in the Cartesian space of robot. The planning algorithms calculate the natural coordinates of actuators using data from a tier of reference trajectory computations, which is an element of the functional structure of an intelligent robot control system. These algorithms are indispensable for programming tools, which connecting a vision tier with a drive control tier.

Author has designed the PLAN2, the program based on motion planning algorithm for a series of IRb-6 manipulator tasks. The reference Cartesian coordinates of the points through which a planned trajectory will pass, will be called main fulcrums. Planning requires a preliminary description of the trajectory, in the form of values of Cartesian coordinates at least two main fulcrums, optionally distant from each other. In case of a kinematics singularity occurrence, the PLAN2 algorithm announce the state, gives the values of acceptable natural coordinates for the links, and asks the user which of the given values are to be accepted. The PLAN2 algorithm calculates additional fulcrums for either defined or non-defined kinematics between the successive fulcrums.

The algorithm for defined kinematics contains four basic segments; the computations from there are transmitted to 22 ancillary segments. The basic segments are: the master segment, the ROZ1 segment, the ROZ2 segment, and the ROZ3 segment. To simplify the description, the following abbreviations will be used: MRF - main fulcrum and AFP - additional fulcrum.

After starting, the PLAN2 algorithm asks about the l_6 and λ_6 parameters, which described the task. Then, it asks about the number MP ($\leq$50), Cartesian coordinates and reference parameter T for the consecutive MFP, and whether the consecutive MFP orientation is defined. If the orientation is defined, the algorithm asks if it is computed. If so, the next question is which coordinate system is used: Cartesian, cylindrical or spherical. After setting required coordinate system, z-y-z Euler angles are computed, describing the orientation of a given MFP. If the defined orientation is not computed, a question about MFP Euler angles appears. For a non-defined MFP orientation, the Ψ_{ref} angle is being set arbitrarily. The Φ_{ref} and Θ_{ref} angles are calculated from the x_{ref}, y_{ref}, z_{ref} Cartesian coordinates.

For the so computed x_{ref}, y_{ref}, z_{ref}, Φ_{ref}, Θ_{ref}, Ψ_{ref} Cartesian coordinates, describing the consecutive MFP, the algorithm calculates the $\mathbf{T}_{ref}$ matrix, checks whether the key equation is satisfied, and computes $\Theta'_1 \div \Theta'_5$ natural coordinates from the formulas, which are an analytic solution of an inverse problem of kinematics. Then, the algorithm asks about a coordinate system describing the shape of a trajectory segment between the consecutive MFPs. For a rectilinear system, a Cartesian coordinate should be chosen; for a curvilinear segment, either a cylindrical or a spherical system should be chosen. Next algorithm asks about the discretization step ΔT along the present reference trajectory segment. After the shape and discretization step along each segment between the consecutive MFPs have been defined, the algorithm asks about the admissible DP

error of position and the DF error of orientation. If an optional task orientation was set earlier, the algorithm arbitrarily accepts DF=360°.

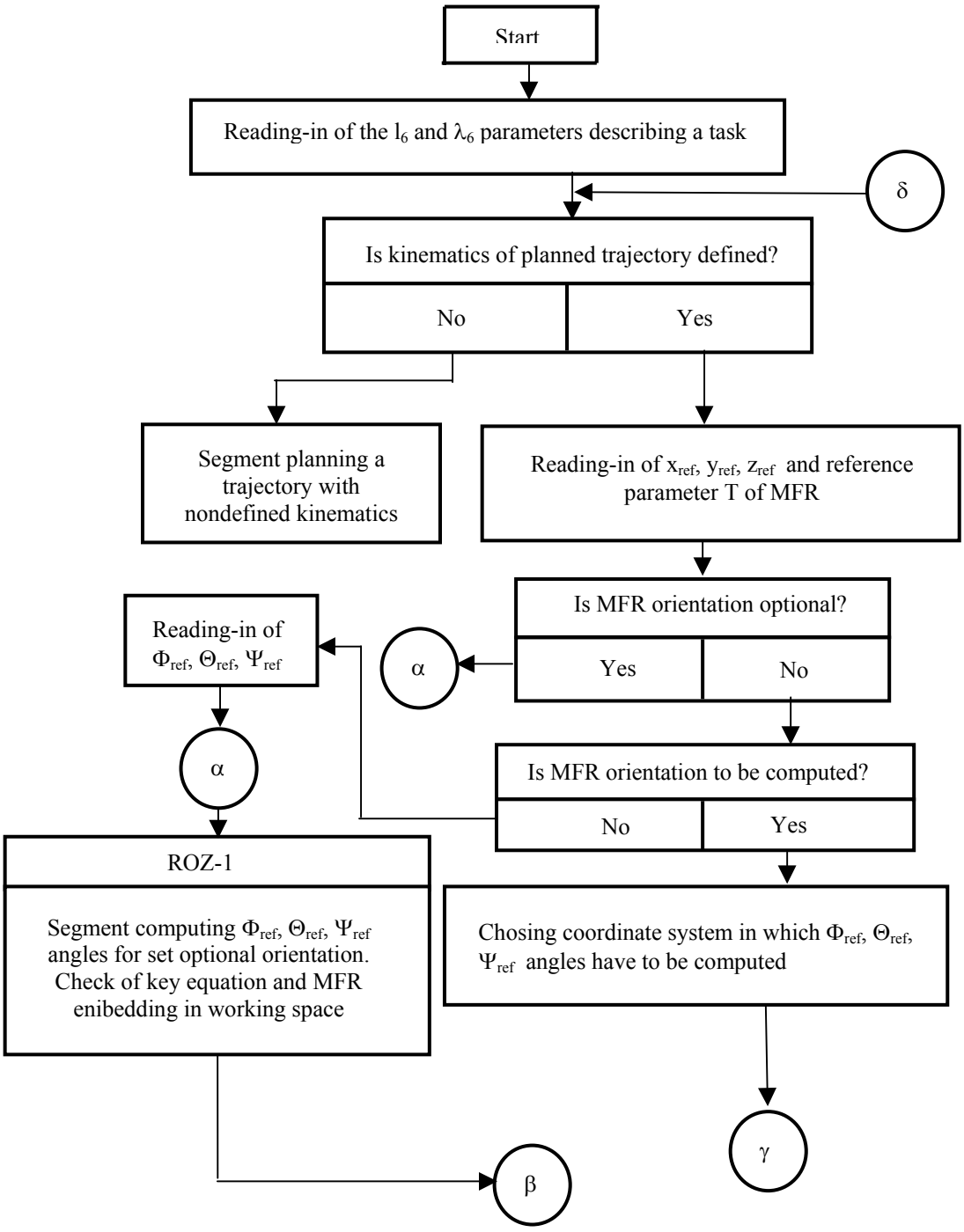


Fig. 4. PLAN2 algorithm block diagram (part 1).

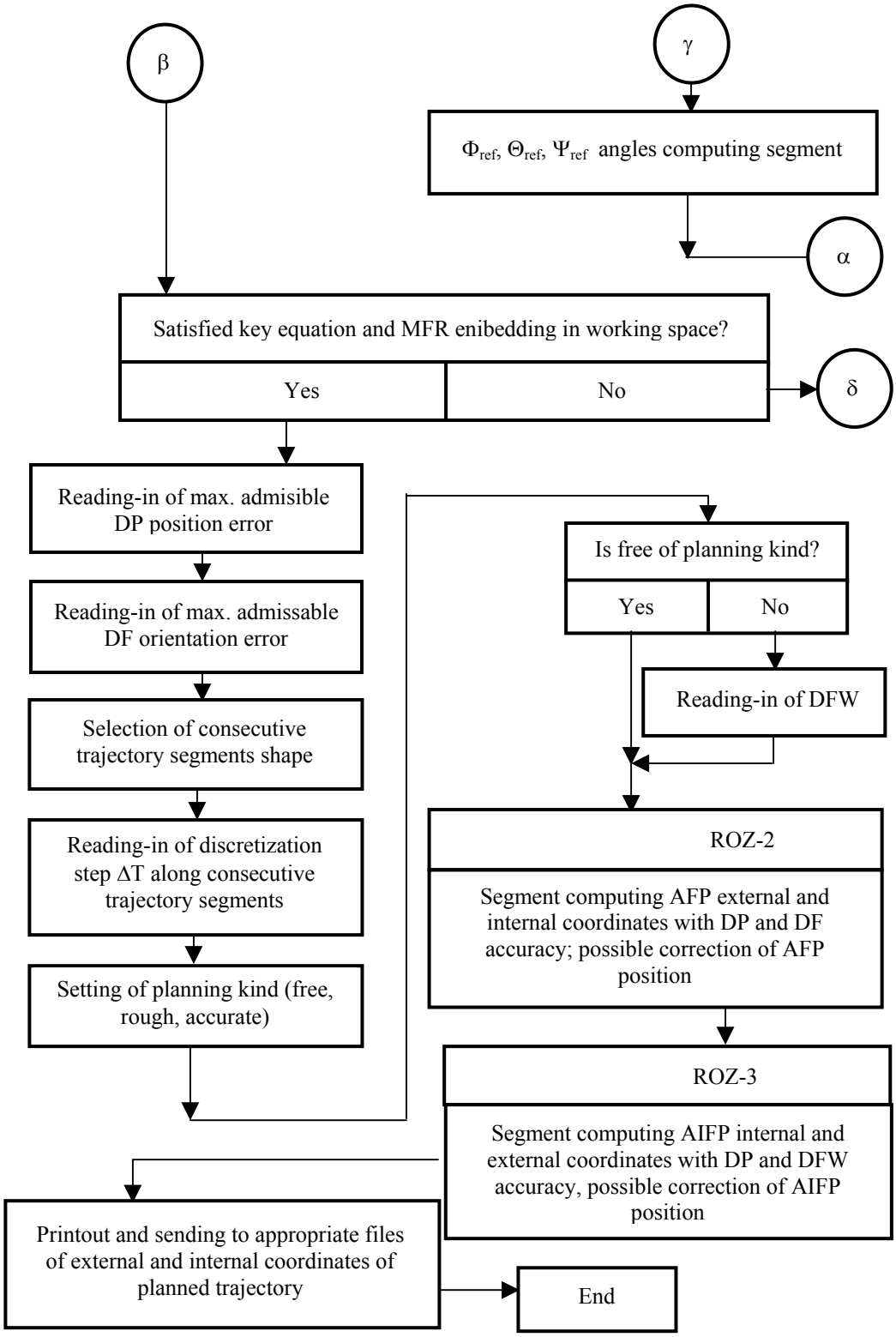


Fig. 4. PLAN2 algorithm block diagram (part 2).

Next, the algorithm asks about kind of trajectory planning, which may be set as: free, rough or accurate. When either rough or accurate planning has been set, a question about an admissible DFW error of orientation is formulated. This parameter is necessary for the manipulator internal space discretization. For a free planning, the algorithm computes the AFP Cartesian coordinates coming from the pre-set DP, DF and step ΔT, which ensure the declared shape of the trajectory segment in Cartesian space.

For a rough or accurate planning, the algorithm computes two groups of fulcrums: additional external fulcrums and additional internal fulcrums. The additional external fulcrums are computed in the same way as in the case of trajectory free planning, and will be denoted as before, using the abbreviation AFP. Additional internal fulcrums result from the division of actuator natural coordinates (within ranges corresponding to consecutive AFPs) and are denoted using the abbreviation AIFP. Each range of actuator natural coordinates corresponding to consecutive AFPs is divided into N+1 parts. For a rough planning the number N results from the minimal angular ratio orientation errors. For an accurate planning the number results from the longest effective radius of task displacement in Cartesian space.

The final result of the algorithm is to generate sets describing all manipulator internal and Cartesian coordinates. Figure illustrates a block diagram of the PLAN2 algorithm for the defined kinematics of the task reference trajectory.

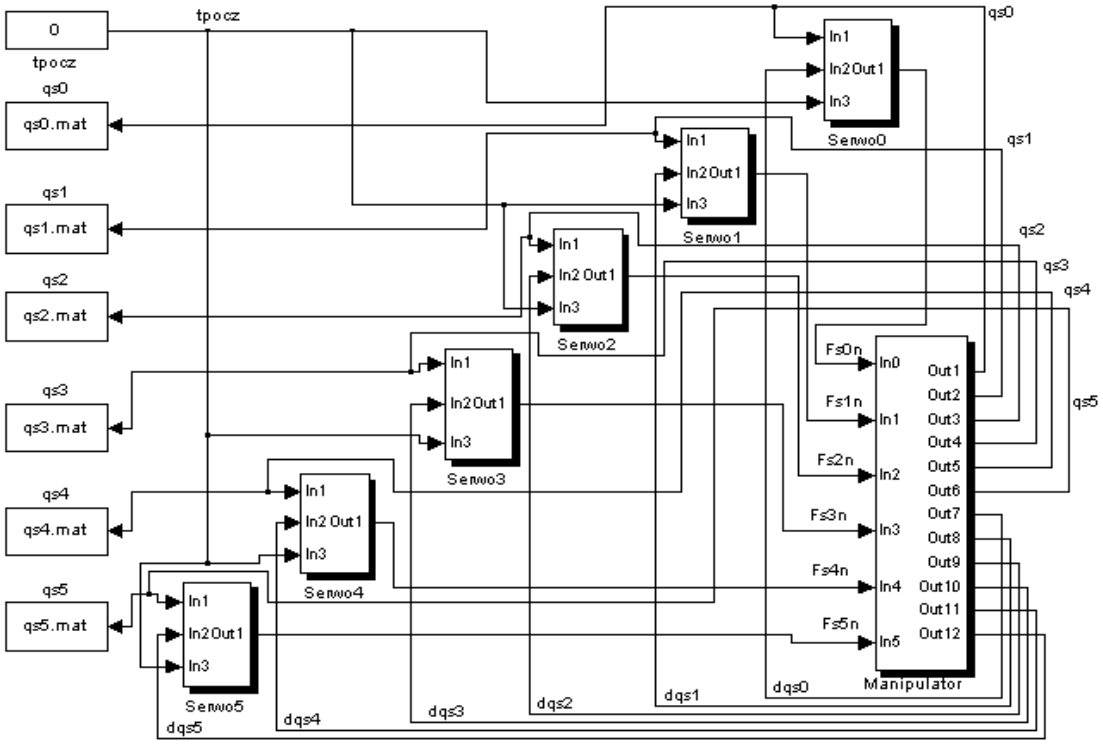


Fig. 5. The graphic model of experimental robot.

This algorithm has been implemented partially to control system of experimental robot. Implementation allows to reach by experimental robot points, which were determined

by optical measurements. Ones allows on straight line movement of the experimental robot task.

To simulation of movement and control of these robots the graphic model was designed. The model was worked in Simulink integrated with Matlab and it is in Fig.5 presented. The graphic model contains mathematical models of kinematics and dynamics of manipulators, models of motors, servos, master and slave controllers. The kinematics models describe a movement of links and a movement of chosen elements transmitting drive and motors. In this model the friction moments and distribution mass of following elements: links, chosen elements of transmitting drive, gripper, manipulation object and motors are taking into consideration. Closed form of kinematics and dynamics coefficients was obtained using Symbolic Toolbox Math. The motors model describes voltages, currents and drive torques. The graphic model contains the mathematical model of servo controllers and power amplifiers too. The simulation programs in C were obtained automatically from the graphic model, by means of the Real Time Workshop extension of Simulink. With the aid of the extension Real Time Workshop we may automatically create also a source code for the simulation program in the assembler of various processors.

Methods for simplifications of manipulator dynamic models were developed. The methods based on research on the sensitivity mass forces to mass parameters, which appear in closed form of dynamics equations.

Microcomputer system for preventive maintenance of industrial ventilators

A. Staszulonek

There are hundreds of thousands industrial ventilators working globally in a continuous mode. They are frequently used in the processes where undisrupted air or other gases transportation is critical for plant or process functioning. Almost always these ventilators work completely unsupervised or at best are periodically checked with the professional, portable equipment. This happens usually when noticeable malfunctioning occurs. Frequency of this checkup is thus very seldom and usually too late to prevent significant damage of the equipment. Test and measurement equipment used for this checkup is highly expensive and requires qualified personnel to install, carry diagnostic tests and interpret the test results. All this results in high repair cost, extended process breakdown time and related financial losses.

To eliminate these problem a continuous, predictive maintenance of industrial ventilators should be applied. To implement this innovative idea a dedicated microcomputers system has been developed. The block diagram of this system is presented on the figure below (Fig.1.).

The system is furnished with the set of sensors measures relevant parameters, like vibrations, noise, current, voltage, temperature, pressure, flow or other values depending on the application. Data is processed on site, machine state indicators are calculated and the results transferred to the local workstation. Machine state indicators are transferred to the preventive maintenance database server. Data are analyzed by the diagnostic software, machine failures are predicted and warnings are communicated to the appropriate persons and systems. Machine state indicators are archived for future use.

The Fast Fourier Transformation (FFT) is performed by the system onsite and the results are transmitted to the monitoring station. All the results can be viewed there.

The sample result presenting the acceleration and FFT results is presented on the figure below (Fig.2).

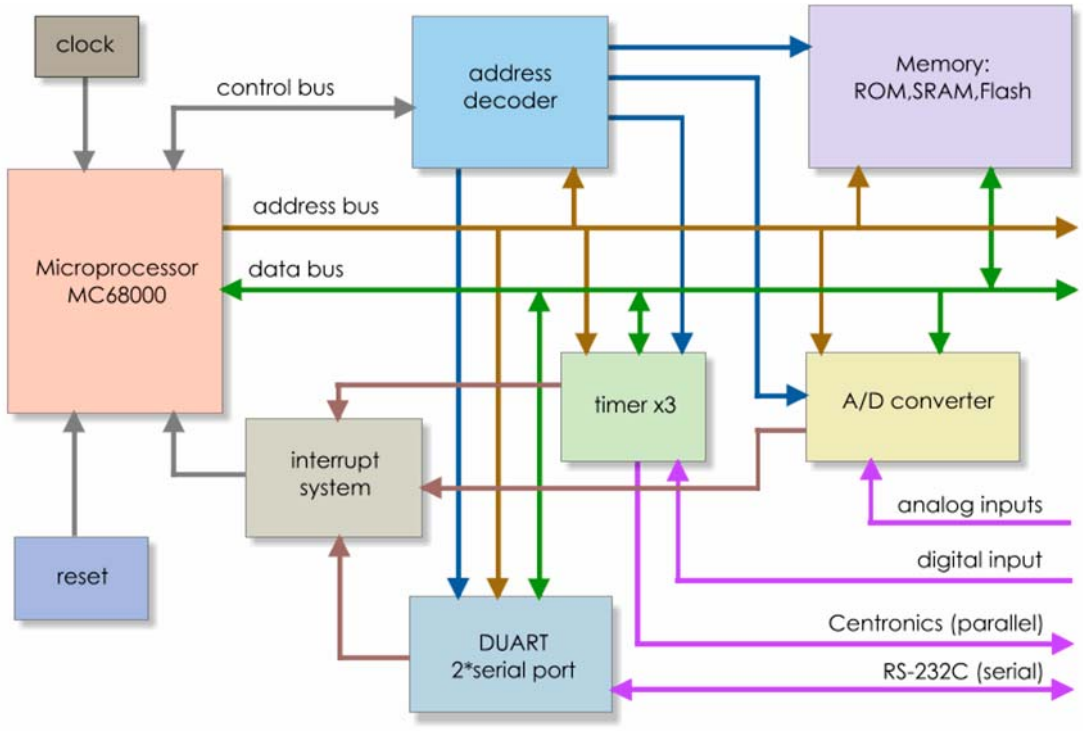


Fig. 1. Block diagram of the diagnostic system.

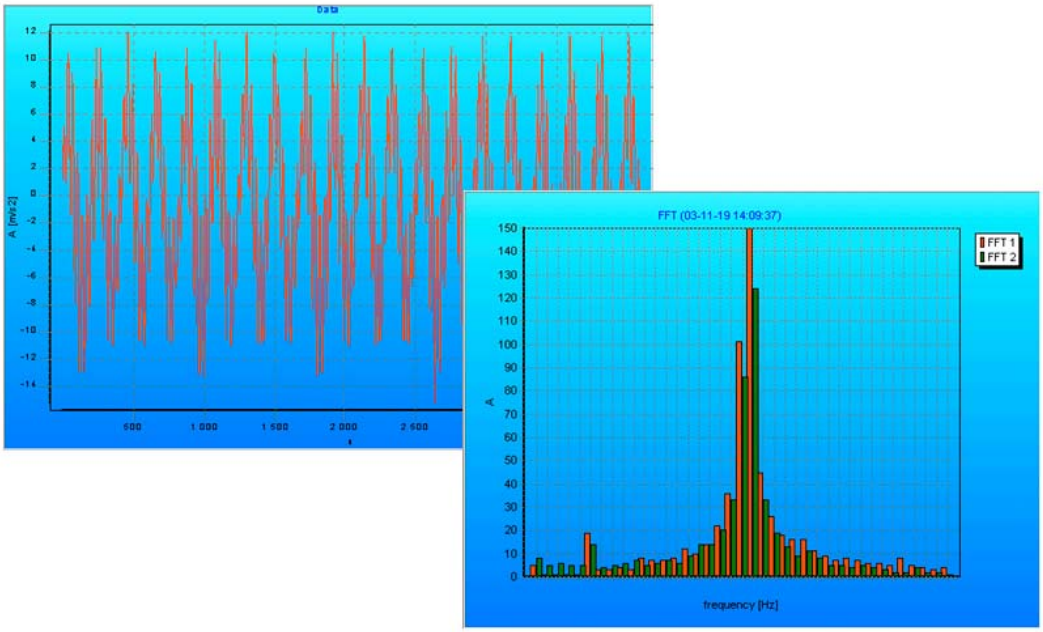


Fig. 2. FFT analysis of vibrations - sample result.

All the data generated by the system are stored at the database for the analytical purposes. The structure of the database is presented below.

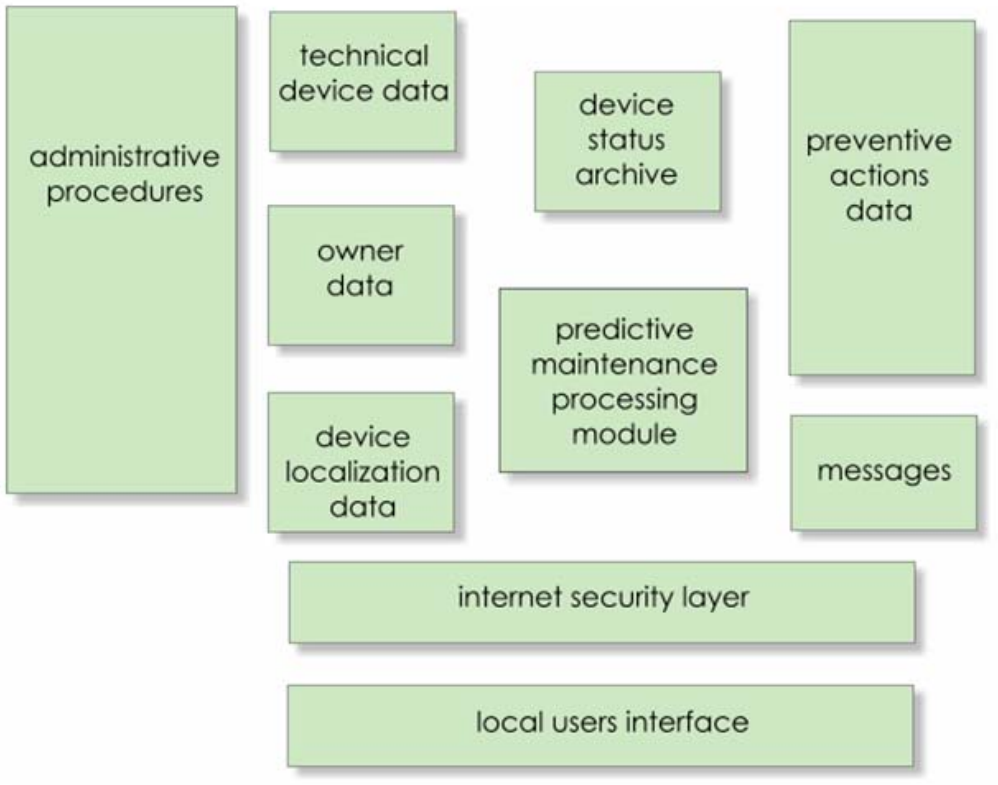


Fig. 3. Components of predictive maintenance database.

Based on these data a forecast process generating the predictive maintenance curve is carried out. The state of the equipment and the time of recommended maintenance action are resulting from this curve.

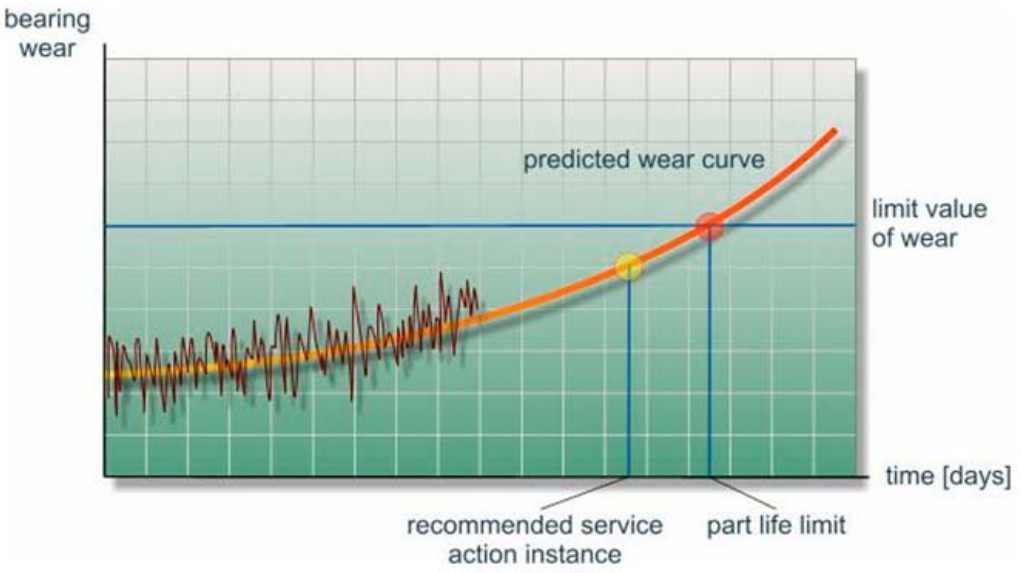


Fig. 4. Predictive maintenance curve.

In case of rapid deterioration of any of the monitored parameters the alarm messages are distributed over the Internet to the appropriate recipients like: owner's tech support, external tech support, manufacturer and any other person or unit indicated.

Hardware structure of advanced robot control system

A. Staszulonek

Between the basic requirements set on advanced robot control systems one can mention the following:

- High precision of robot arm positioning and tracking,
- High speed of motion,
- Rich set of interfaces to the sensory systems,
- Trajectory repeatability in the presence of various disturbances,
- Simple design and maintenance,
- High reliability,
- Lack of overshoots during the transient processes.

Last of the above mentioned requirements is critical. Due to these requirements the robot control system has to perform simultaneously and in real time large number of tasks. Between these tasks are following: desired trajectory planning and generation in presence of variable work space, elimination of inertial cross couplings, acquisition and processing of sensory information, control of multiple degree of freedom servomechanisms, robot motion visualization and general system monitoring. These tasks represent significant computational load and by far exceed the power of single processor. Due to the nature of the calculations performed robot control system's task can be classified into group performing the floating point operations and, the group performing the integer calculations. For the above-mentioned reason the robot control system can be divided into two dedicated subsystems. First of these subsystems is loaded with task planning, decomposing and execution supervision. The output from this subsystem is the desired robot trajectory specified as the point-to-point or continuous motion. In the first case one has to deal with the set point control problem while in the second with the tracking problem. For both cases the methods the methods used to solve the problem differ significantly. Second of the above mentioned subsystems, in a way subordinate to the first is the one whose task is the execution of the generated trajectory. It usually consists of one or more dedicated computers, controlling each of the manipulator's servomechanisms. The figure below presents the hierarchical, multilevel, multiprocessor hardware structure of advanced robot controller reflecting the task assignment between the two subsystems. Presented structure incorporates two single board computers: MVME2604 and MVME162 cooperating over the standard VME bus. Each of these computers has the set of interfaces and peripheral devices appropriate for the performed tasks. The information exchange between both computers (and subsystems) is carried out via the shared area of system memory. The access to this memory is coordinated by an appropriate set of semaphores. At the upper, supervisory level of the system the RISC processor based machine MVME2604 has been applied. The particular tasks performed at this level are: desired trajectory generation, reverse kinematics problem solution, pseudoinertial matrix calculation, inertial decoupling, motion visualization, system monitoring and robot program storing. This level of the controller is provided with SCSI CD-ROM and Hard

disk to enable easy system software installation and storage of the application software. The operator communicates with the system via the SVGA monitor connected to MPMC graphic card, standard keyboard and mouse. The users access the system via the local area network Ethernet. This level is controlled by the AIX R4.3 operating system.

The software development is carried on with the C++ programming language, while as the graphic environment the X-Windows system is used.

Embedded computer MVME162 has been applied at the lower level of system. Its major tasks are: servomechanisms control and sensory data acquisition. To increase the speed of system, the calculations at this level are mostly performed on the integer numbers.

All activities of the system at this level are interrupt driven. Due to the high data sampling rate required, the computational load at this level is very high. In particular, high sampling rates are required for manipulator links position and velocity acquisition. This justifies the necessity of multiprocessor structure of the whole system.

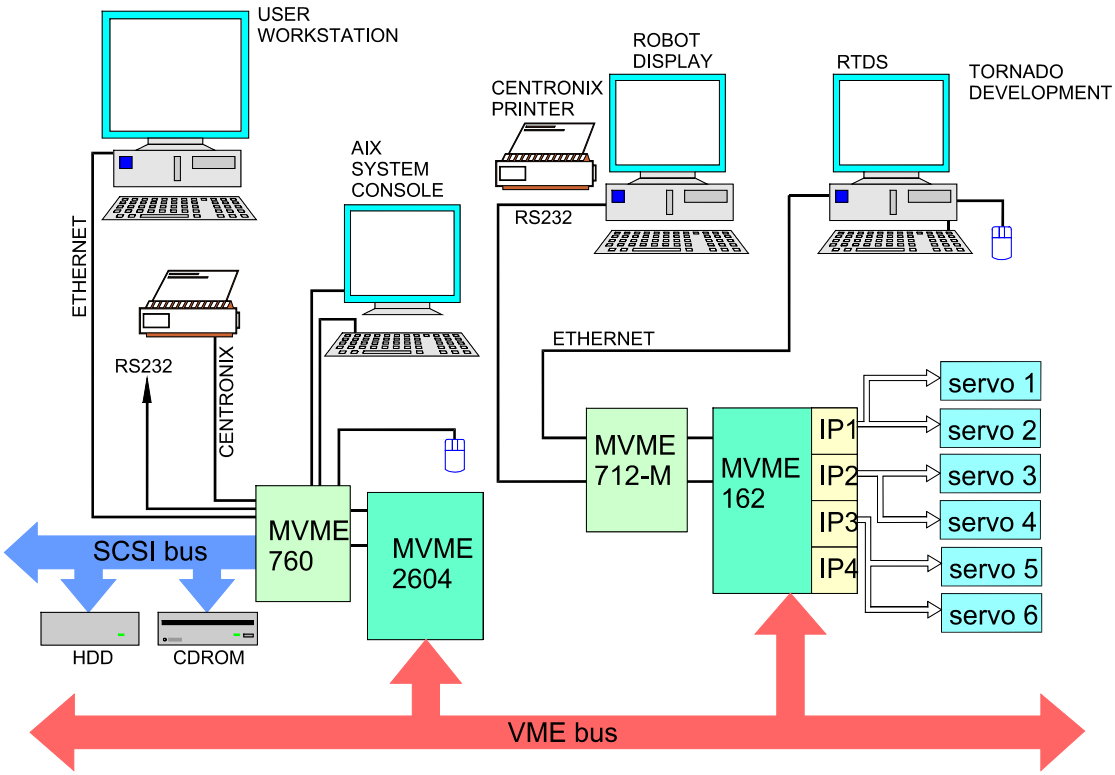


Fig.1. Hardware structure of robot control system.

To achieve high sampling rate, the embedded controller at the trajectory execution level has been provided with six dedicated servocontrollers based on specialized motion controllers LM628 organized into three Industry Pack standard modules. Real time operating system VxWorks is responsible for the system coordination at this level. The application software for the trajectory execution level is created in assembly language, high-level C, and object C++.

The development process is carried on in the Tornado and Windows environment on common PC computer. The communication between development system and embedded controller is carried on via the Ethernet. Additionally the terminal can be connected directly to the embedded controller. This terminal can be used as the

low-level system console, displaying various information concerning the task performed and current trajectory execution.

COLOUR IMAGE PROCESSING

Research on colour image processing

H. Palus, D. Bereska

Colour image processing has a history going back over 30 years but such systems have been undeveloped in the past. Research in this field required high performance computers, colour cameras, special framegrabbers and colour monitors. Binary and grey-level image processing were therefore much easy. Nowadays, the role of colour in image processing cannot be understated. The situation in many subtopics of image processing has changed: colour images are commonplace and monochromatic images are rather exceptional.

Our research concentrates on the following low-level colour image processing problems: acquisition of high-quality colour images, representations of colour images in different colour spaces, pre-processing methods (edge preserving filters, colour quantization etc.), colour image segmentation techniques and evaluation of segmentation results. In practise there does not exist an ideal colour space for all stages of image processing process. The decision on which colour space to use depends on given task.

We investigated the properties of HSI perceptual colour space. The HSI colour solid was visualised and the number of colour points in horizontal sections through this solid was calculated. The knowledge about a structure of colour space can be helpful for improvement of procedures in low-level stage of colour image processing and recognition e.g. colour image segmentation. We reviewed also different standard RGB colour spaces on the background of device-dependent RGB colour space and observed some limitations of standards. Experiments with images of Gretag Macbeth ColorChecker Chart (Fig.1) acquired by the digital still camera were conducted. The knowledge of colour gamut of digital camera was very important for determining the colour transformation from RGB to CIELAB. In experiments the reference data for colours was the CIELAB components measured by spectrophotometer.

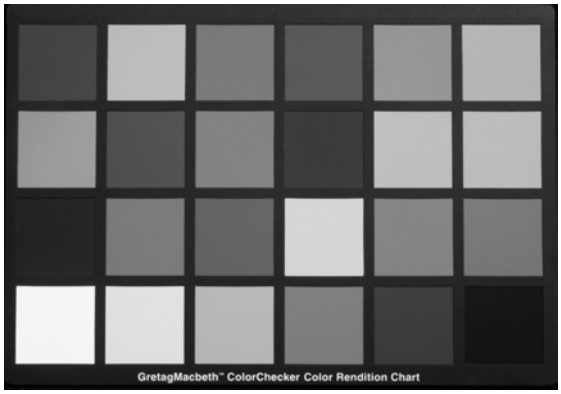


Fig. 1. ColorChecker Chart from Gretag Macbeth.

Higher colour reproduction accuracy in case of using the sRGB colour space was shown. New colour-difference formulae CIE94 and CIEDE2000 have been proved successful in evaluating colour reproduction accuracy.

Colour image segmentation plays an important role in many applications e.g. object recognition, image compression, content based image retrieval etc. An error in this process will be propagated further. The goal of colour image segmentation is to identify homogeneous regions in colour image that represent objects or meaningful parts of objects present in a scene. One of simplest methods of colour image segmentation is thresholding of image. The thresholds are defined as results of analysis of histograms of colour components. In the case of using HSI colour space a hue histogram plays the special role. Sometimes the hue histogram shows colours that do not appear in the image and it is not fit for analysis of histogram for the purpose of location of thresholds. This histogram needs any correction based on the expansion of the idea of achromatic pixels in quasi-achromatic pixels direction. We have proposed a set of additional IF-THEN rules, which link intensity and saturation together for quasi-achromatic pixels and generate corrected hue histogram.

We developed also new algorithms from two main classes of segmentation techniques: pixel-based techniques and region-based techniques. Clustering in image processing is the grouping together of pixels from an image, depending the calculated similarity between them. Clustering can be often defined as an unsupervised classification of pixels. The image data is clustered in three-dimensional colour space (usually RGB). Many colour clustering techniques have been proposed in the past. We shortly describe here three classical and two less popular clustering techniques suitable for segmenting of colour images. All these techniques are iterative. We asserted that evaluation functions VM and Q could be very helpful in search of best segmentation results during clustering process. Additional criterion for the choice of clustering technique can be the time of computing: from fast k-means to slow cluster merging technique. We observed that the postprocessing stage is very important for the segmentation results.

During last years we are developing an original region-based segmentation technique for colour images. This technique is based on the concept of region growing without seeds and, in postprocessing process, on a small regions removal by region merging. Experimental results of proposed segmentation technique are good. We tested our technique working in different colour spaces (RGB, CIELAB and HSI). An additional region merging procedure removes oversegmentation results and small highlights. Majority of colour segmentation techniques uses several control parameters, e.g. a number of clusters in clustering techniques or some values of thresholds in region-based segmentation. These parameters should be adjusted to obtain optimal image segmentation. The choice of values of parameters is non-trivial task. This segmentation technique was also used in process of grey-scale segmentation of the comet assay images. The comet tail and head were successfully extracted.

The segmentation results are strongly determined by a control parameters: threshold $\boldsymbol{d}$, which limits the value of homogeneity criterion and threshold $\boldsymbol{A}$, which defines an area of small region used in postprocessing (Fig.2). During this merging process each region with a number of pixels below $\boldsymbol{A}$ is merged into a region with a larger area if the homogeneity criterion is fulfilled. After the merging, a new mean colour of region is calculated and the labels of pixels belonging to a region are modified. Experimental investigations of presented segmentation technique were performed using F and Q evaluation functions. The idea of using this kind of functions can be formulate as: the

lower is the value of F or Q, the better is the segmentation result. If quantitative evaluation function of segmentation results is applied then a choice of values of parameters is simpler. The segmented images can be further postprocessed e.g. by removing small regions that are usually not significant in further stages of image processing.

Fig. 2. Example of segmentation results in RGB colour space for image Peppers: original image (left), parameter value: **d**=30 (middle), parameter values: **d**=60, **A**=500 (right).

In the case of noisy images, we propose the different filters that can be applied as pre-processing stage for colour image segmentation. Next we address the problem of performance of preprocessing before colour image segmentation. Our interests are limited to nonlinear colour filters working in the spatial domain. Most often comparing such filters is based on calculation of different quality factors (e.g. PSNR, NCD etc.). Our main idea here is to use an evaluation function, coming from research on segmentation, to evaluate the performance of preprocessing. The experiments were realized using both original and noisy images corrupted by Gaussian and impulsive noise.

Last topic of our research in the field of colour image processing is based on the concept of colourfulness. Colourfulness of the image is main attribute for image quality assessment. We have shown different methods of defining and computing of colorfulness of the image. All experiments have been carried out on the set of natural color images with different perceptual colorfulness. We have tested the images using simple colorfulness estimate based on statistical parameters of the pixel cloud along red-green and yellow-blue axes. During image processing the colorfulness of the image can be changed: by increasing after color enhancement or by decreasing after image compression. Sometimes the colorfulness of the image should be invariant. We have presented it on examples, which show that the colorfulness can be useful for evaluating the color quantization algorithms beside such traditional performance functions as RMSE and ΔE. Based on these experiments, we can formulate more general conclusion: concepts coming from colour science can effectively applied in colour image processing.

GRADUATE COURSES

Members to the RDEA Group are involved in teaching the following courses:

- Operations Research,
- Modelling and Simulation,
- Automated Manufacturing Systems,
- Production Control,
- Flexible Manufacturing Systems,
- Expert Systems,
- Foundations of Robotics,
- Power Transmission Systems and Industrial Robots,
- Robot Control Systems,
- Manipulator Systems,
- Sensor Systems,
- System Dynamics,
- Electrical Engineering and Mechanics,
- Microcomputer Programming,
- Microcomputer Systems,
- Computer Integrated Manufacturing,
- Robot Vision,

INDUSTRIAL ROBOTICS RESEARCH LABORATORY

An advanced robot control systems research and development laboratory has been created at the RDEA Group during recent years.

The experimental setup consists of the following components:

- the kinematic and mechanic structure of robot IRb-6,
- advanced, multilevel robot control system,
- X Windows graphic environment,
- VxWorks real time operating system,
- application software under development.

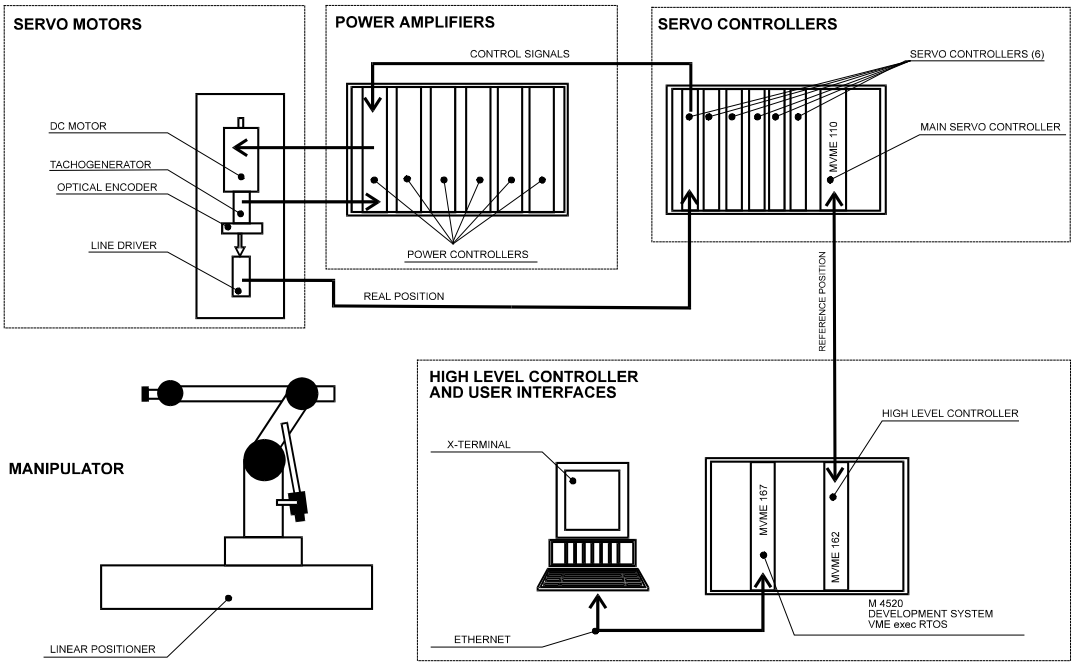
The advanced robot control system for robotic research has been entirely designed and implemented of the RDEA Group. The sensorial part of IRb-6 system has been modified according to the design.

An innovative approach to the problems of servocontrol, trajectory generation and robot programming language has been adopted. This approach results in the unique, high quality control software. The simplified block diagram of the experimental system is presented on the figure below.

A variety of research works can be carried out at this laboratory. Among these works one can mention the investigations in the following areas:

- servomechanisms control algorithms,
- robot programming languages,
- task planning and decomposition,
- trajectory generation,
- inertial decoupling,
- vision systems,

- sensor information processing.



RESEARCH STATION

The laboratory of robot control systems is accessible for researchers active in the above mentioned areas and for the industrial engineers who wish to become familiar with the most advanced microcomputer control systems technology.

NEW STRUCTURE OF THE INSTITUTE

New challenges in education and research, which the Institute have been confronted with, resulted in partial reconfiguration of its structure in the fall 2004. A group of researchers from the Control Theory Group led by Prof. Swierniak has been for quite a long period of time involved in number of projects related to application of system theory and signal processing techniques in biology and medicine. It was maid with a team from the Robotics and Discrete Events Automation Group engaged in research on discrete events systems. THe new group has been called the **Systems Engineering Group**.

Researchers engaged in projects on robotics joined the Control Theory Group whose name has been changed to **Control and Robotics Group**.

The name of the Industrial Control Group has been changed to **Computer Control Group**.

The two rearranged group of the Institute have the following membership.

* Control and Robotics Group

Head:

Ryszard Gessing, M.Sc., Ph.D., D. Sc., full-titular professor,

Members:

Adam Czornik, M.Sc., Ph.D., D.Sc., associate professor,
Marian Błachuta, M.Sc., Ph.D., D.Sc., professor,
Zdzisław Duda, M.Sc., Ph.D., D.Sc., professor,
Andrzej Polański, M.Sc., Ph.D., D.Sc., professor,
Damian Bereska, M.Sc., Ph.D., - assistant professor,
Roman Czyba, M.Sc., Ph.D., - assistant professor,
Adam Gałuszka, M.Sc., Ph.D., assistant professor
Zygmunt Kuś, M.Sc., Ph.D., assistant professor,
Aleksander Nawrat, M.Sc., Ph.D., assistant professor
Krzysztof Simek, M.Sc., Ph.D., assistant professor,
Zbigniew Starosolski, M.Sc., Ph.D., assistant professor,
Aleksander Staszulonek, M. Sc., Ph.D., assistant professor,
Tadeusz Szkodny, M.Sc., Ph.D., assistant professor,
Andrzej Czarnecki, M.Sc., assistant,
Artur Babiarz, M.Sc., Ph.D. student,

Robert Bieda, M.Sc., Ph.D. student,
Rafał Grygiel, M.Sc., Ph.D. student,
Krzysztof Jaskot, M.Sc., Ph.D. student,
Roman Jamorski, M.Sc., Ph.D. student,
Maria Łuszczkiewicz, M.Sc., Ph.D. student,
Marcin Pacholczyk, M.Sc., Ph.D. student,
Krzysztof Skrzypczyk, M.Sc., Ph.D. student,

Jarosław Homa, technician,
Jan Skrzyniarz, technician,
Mirosława Żywiec, technician,

*** Systems Engineering Group**

Head:

Andrzej Świerniak, M.Sc., Ph.D., D. Sc., full and titular professor,

Members:

Marek Kimmel, M.Sc., Ph.D., D. Sc., titular professor,
Bogdan Smołka, M.Sc., Ph.D., D. Sc., associate professor,
Zbigniew Bortliczek, M.Sc., Ph.D., assistant professor,
Waldemar Grzechca, M.Sc., Ph.D., assistant professor,
Krzysztof Fujarewicz, M.Sc., Ph.D., assistant professor,
Mieczysław Jagodziński, M. Sc., Ph.D. assistant professor,
Jolanta Krystek, M. Sc., Ph.D., lecturer
Bożena Paluchiewicz, M.Sc., Ph.D., senior-lecturer,
Henryk Palus, M.Sc., Ph.D., assistant professor,
Joanna Polańska, M.Sc., Ph.D., assistant professor,
Witold Sileikis, M.Sc., Ph.D., assistant professor,
Jarosław Śmieja, M.Sc., Ph.D., assistant professor,
Marek Szczepański, M.Sc., Ph.D., assistant professor,
Artur Bal, M. Sc., assistant,
Damian Borys, M. Sc., Ph.D. student,
Łukasz Indeka, M.Sc., Ph.D. student,
Krzysztof Puszyński, M.Sc., Ph.D. student,
Tomasz Primke, M.Sc., Ph.D. student,

Elżbieta Król, M. Sc., engineer,
Andrzej Fortuna, M. Sc., engineer (half-time employed)
Aleksandra Szczerbik, M.Sc., engineer,
Edward Szumiński, technician,

Systems Engineering Group

The activity of the **Systems Engineering Group** is concentrated in three main domains:

- biological applications of system theory and bioinformatics,
- image processing and pattern recognition,
- discrete events systems and computer integrated manufacturing.

It is interesting that these three branches in spite of their different roots can be efficiently applied in a number of projects in genetics, functional genomics, molecular biology as well as support medical diagnosis and design of therapy. Therefore, along with theoretical research activities, which are still performed in collaboration with researchers from other groups (mainly Control and Robotics Group), the Systems Engineering Group is engaged in a number of projects developed in collaboration with the Institute of Oncology. These are directed towards classification, clusterization and selection of gene expression data from microarray experiments, modeling and control of cancer population growth, statistical analysis of DNA damage/repair process, pattern recognition, filtration and disturbance enhancement of biological images including gene and protein gels, DNA micoarrays, and results of various diagnostic investigations and finally operation research and artificial intelligence tools in genomics and molecular biology. To meet the challenges in this area two new laboratories have been created:

Research Laboratory of Computational Biology

To solve complex problems more and more often we have to use very advanced and time and memory-intensive computations. These computations may last too long if we utilize personal computers. In addition, data generated and processed during the computations may have enormous size, impossible to store in common-use machines. To make such calculations possible our research laboratory was created.

The basic field of research realized in this laboratory is implementation of algorithms that facilitate the understanding of biological processes through the application of statistical and machine learning techniques. Because these methods are often compute-intensive and often accumulate huge amount of data from biological and chemical experiments such as DNA microarray chips and mass spectometry we attempt to create algorithms that are efficient, based on existing hardware architecture.

In the laboratory we have four high-end servers which compose the total of 7 CPU's (3 machines are dual processor systems based on Intel Xeon HyperThreading architecture), 12 GB of RAM and about 1.4 TB of disc space. Whole system is connected by low-latency local network (1 Gbit ethernet) to create High Performance Computing cluster, which is also named Beowulf cluster – a unified system for parallel computing.

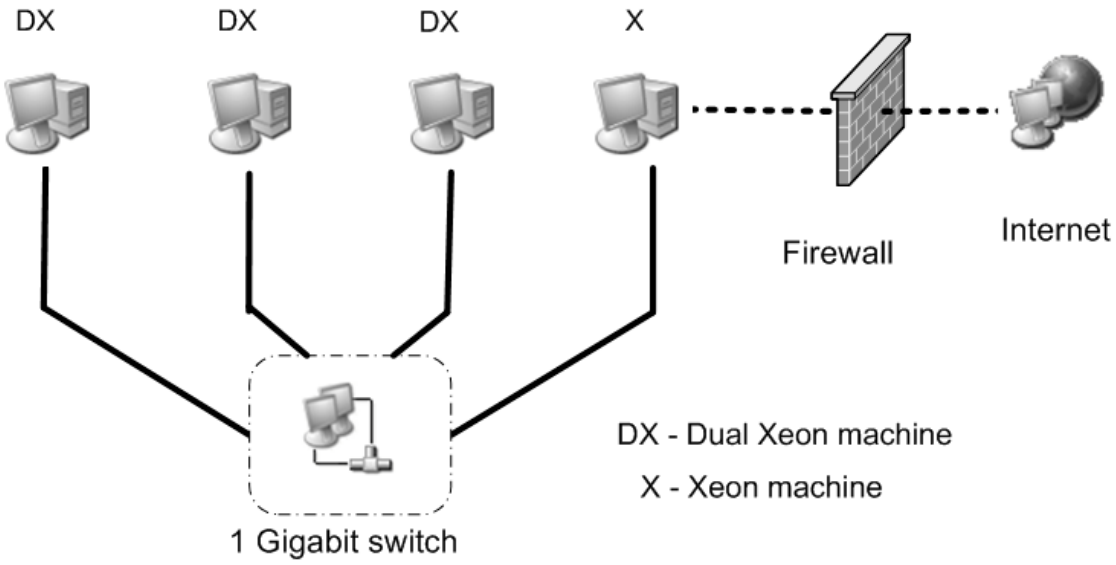


Fig. 1. Hardware cluster architecture.

This cluster is based on Linux platform and software package based on message-passing paradigm (distributed memory virtual computers such as PVM – Parallel Virtual Machine or MPI - Message Passing Interface). Users can create and execute programs written in C, C++ or FORTRAN programming languages or can take the advantage of highly developped scientific environments like Matlab, R or others.

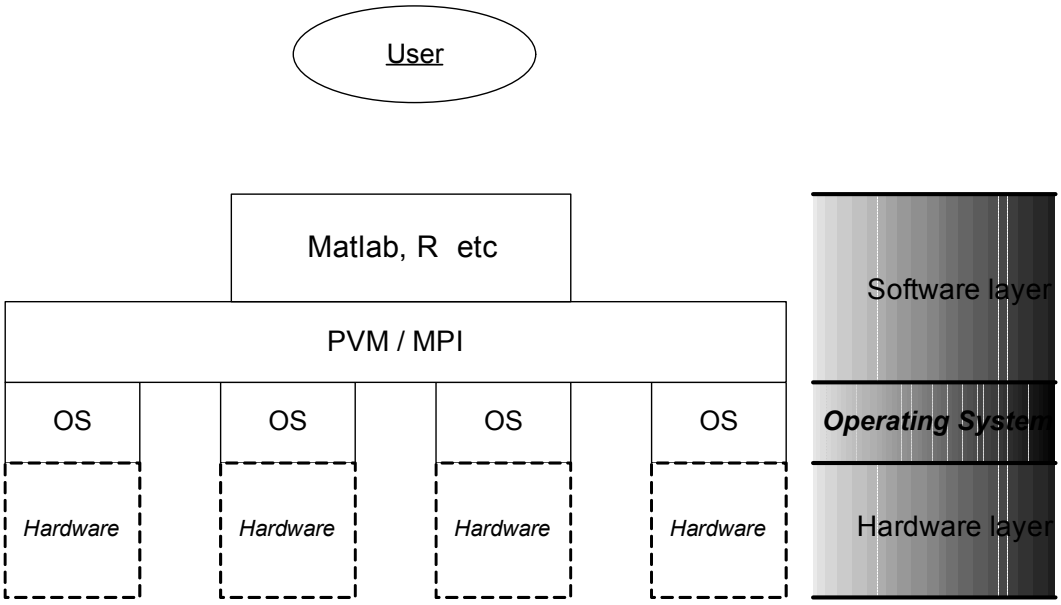


Fig. 2. Software architecture.

Laboratory of Digital Archiving

One of our research topics is the digital heritage preservation. As it is obvious that historical documents are one of the most valued cultural heritages of any nation, for centuries, incunabula, maps, music sheets, manuscripts, facsimile and old prints have been carefully stored, archived and protected over times of wars and natural disasters, in order to preserve them for future generations. Unfortunately, the historical documents deteriorate with time in many ways. Vellum, canvas, paper, ink and print are exposed to aggressive chemical, physical and biological factors, which in turn leads to slow but inevitable and permanent loss of valuable exhibits.

This great danger is forcing to take prompt counter-measures in order to preserve our cultural heritage for future generations. Because of the inevitable process of total natural destruction that is due to happen to many items in the nearest future, the only way of preserving the collection is to save the information content and make exact copies of originals using analog or digital acquisition of document images.

We are convinced that modern techniques of digital collection, storage and display are the only durable and relatively cheap way to preserve the information value of documents and the only effective method of making public the knowledge about collections of documents preserved in museums and libraries.

Such actions allow securing informational values of the documents and making them available to general public. It is especially important considering the fact that optimal document storage conditions, i.e. in separation from damaging external influences, often limit the access to the documents, even making them unavailable to larger groups of specialists.

Archiving the information layer of the document indirectly prolongs its physical existence, because the need to make the original document accessible is eliminated, at least in majority of the access requests where only the information contained in the document is needed.

Our research work is mainly focused on issues of digital acquisition, image preprocessing, archiving and multimedial presentation of collections.

Laboratory equipment (main elements):

- large format (4×5) view camera Cambo Ultima Digital,
- high-performance digital scan back Better Light 4000E-HS — technical data: uninterpolated resolution 3750×5000, single-pass color or monochrome scanning, continuously adjustable color balance in 0.1 CC steps, 11 f-stop dynamic range,
- four Bowens continuous light source utilizes a specially designed fluorescent lamp to produce a cold, daylight-balanced, safety for historical objects illumination,
- Manfrotto photo and light equipment,
- Lastolite light tens and reflectors.

Fig. 1. Laboratory equipment.

Teaching activities of the System Engineering Group cover the following graduate courses:

- Electrotechnical and electromagnetic engineering,
- Automatic manufacturing systems,
- Pattern recognition,
- Computer aided Drawing and design,
- Final project seminar,
- Large scale systems,
- Computer aided decision making,
- Elements of artificial intelligence,
- Sensor systems,
- Operation research,
- Production control,
- Flexible manufacturing systems,
- Expert systems,
- Computer networks,
- Biosystem modeling,
- Digital acoustic and vision signal processing,
- Biometry,
- Artificial intelligence in biotechnology,

- Neural networks,
- Optimization and control in genetics and molecular biology,
- Information processing in ecosystems,
- Death – and – birth processes,
- System dynamics,
- Optimization methods,
- Computer Integrated Manufacturing,
- Robot Vision,
- Optimisation and Decision Making,
- Hierarchical Control,
- Biotechnical Systems.

Moreover, together with the Control Systems and Control Instrumentation Group, two important educational enterprises are undertaken. The first one started in the fall 2003 initiated new courses in Information Processing and Control in Biotechnology for students in Automatic Control and Robotics. The second one is interdepartmental study in Biotechnology initiated by three Faculties: The Faculty of Automatic Control, Electronics and Computer Science, The Faculty of Chemistry and The Faculty of Environmental and Energy Engineering. Our Faculty is responsible for specialization Bioinformatics for which enrollment will start in the fall 2005.

Publications

Control Theory and System Engineering

Books ans lecture notes

I.1. Czornik A.: On control problems for jump linear systems, Wydawnictwo Politechniki Śląskiej, Seria Automatyka z. 137, Gliwice 2003 (rozprawa habilitacyjna).

I.2. Gessing R., Duda Z.: Estymacja i sterowanie statystycznie optymalne, podręcznik przygotowany do druku, 2005.

I.3. Gessing R.: Control Fundamentals, Wydawnictwo Pol. Śl. ISBN: 83-7335-176-0, Gliwice 2004.

I.4. Świerniak A., Gałuszka A.: Optimization methods and decision making. Lecture Notes, Skrypt Pol. Śl. 2334, Wydawnictwo Pol. Sl. ISBN 83-7335-180-9, Gliwice, 2003.

Chapters in edited books

I.5. Czornik A., Świerniak A., Simek K.: Robust stabilization and optimization of fault tolerant linear systems, Proc. of 2003 IEEE International Symposium on Industrial Electronics, 2003, vol 1, pp. 562-565.

I.6. Czornik A., Świerniak A.: Optimal control of time-varying fault tolerant systems, Proc. of 43 the IEEE conference on Decision and Control, CDC'04, IEEE Press 2004, pp. 1382-1387.

I.7. Czyba R., Błachuta M.: Dynamic Contraction Method approach to robust longitudinal flight control under aircraft parameters variations. Proceedings of the AIAA Guidance, Navigation and Control Conference, AIAA Paper No 2003-5554, Austin, USA, 2003, ISBN-1-56347-638-X.

I.8. Czyba R., Błachuta M.: Flight control design using the Dynamic Contraction Method. Proceedings of 8th IEEE International Conference on Methods and Models in Automation and Robotics, Szczecin, Poland, 2002, pp. 1269-1274.

I.9. Czyba R., Błachuta M.: Robust longitudinal aircraft flight control under atmospheric turbulence. Proceedings of 9th IEEE International Conference on Methods and Models in 2003.

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I.11. Fujarewicz K., Gałuszka A.: Generalized Backpropagation Through Time for Continuous Time Neural Networks and Discrete Time Measurements, Lecture Notes in Computer Science, Springer-Verlag, 2004, 190 -196.

I.12. Fujarewicz K.: Optimization of continuous-discrete systems with a fractional order hold, in: R. Gessing, T. Szkodny, Automatyzacja Procesów Dyskretnych, pp. 35-43, WNT, 2004 (in Polish).

I.13. Gałuszka A., Świerniak A.: STRIPS representation and non-cooperative strategies in multi-robot planning. Proc. 15th European Simulation Symposium (SCS), Delft, October 26-29, 2003, 110-115.

I.14. Gessing R., Czornik A.: About Relation Between LQ and H_2 Optimal Control with Output Feedback. Proc. American Control Conference (IFAC, IEEE, SCS), Denver, 4-6 June 2003, 3508 – 3512, ISBN: 0-7803-7897-0.

I.15. Gessing R.: Parallel Compensator for Control Systems with Nonminimum Phase Plants. Proceedings of American Control Conference, Boston USA, June 30-July 2, 2004, pp.3351-3356, ISBN: 0-7803-8336-2.

I.16. Gessing R.: Parallel Compensator and Its Application to Multivariable Systems. Proceedings of the 10-th IFAC/IFORS/IMACS/IFIP Symposium on Large Scale Systems: Theory and Application, July 26-28 2004, Osaka, Japan, pp.676-681.

I.17. Gessing R.: Relay Control with Parallel Compensator and Nonminimum Phase Plants. Accepted for 16-th IFAC World Congress, 4-8 July 2005, Prague, Czech Republic.

I.18. Gessing R.: Stepwise Return of Integrator Output as a Competition to Antiwindup. Proc. American Control Conference (IFAC, IEEE, SCS), Denver, 4-6 June 2003, 1230 – 1235, ISBN: 0-7803-7897-0.

I.19. Gessing R.: Czy samo sprzężenie zwrotne może zastąpić adaptację. W książce: Automatyzacja Procesów Dyskretnych. Optymalizacja Dyskretna. Robotyka i Sterowniki Programowalne, Wyd. WNT, Warszawa 2004, s. 45-55, ISBN: 83-204-3003-8.

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Professor Kimmel coorganized six international meetings on Mathematical Population Dynamics and edited refereed collections of papers from these meetings. Professor Kimmel is also on the editorial boards of *Mathematical Biosciences*, *Journal of Theoretical Biology*, *Journal of Biological Systems and Journal of the National Cancer Institute*. In 2002 he published a monograph "*Branching processes in biology*" (Springer, together with David E. Axelrod)

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Stanisław Waluś graduated from the Faculty of Automatic Control of the Silesian Technical University in Gliwice in 1970. As an assistant he took part in works connected with automation of oxygen converter process and using of ultrasonic flowmeters for flow-rate measurements. In 1980 he received his PhD degree. He is the co-author of ultrasonic flowmeter, which is produced in Poland. Further scientific works were connected with mathematical modelling of primary devices of various flowmeters and metrological optimisation of sampling flowmeters. In 2004 he received his qualifying as the assistant professor in the scientific discipline automatic control and robotics (speciality: metrology, industrial measurements). He is the author and co-author of over than 90 scientific publications. He published some papers in the scope of didactic of metrology. Also the author of academic manual "Ultrasonic flowmeters. Methodology of using" and monograph nr 43 "Metrological optimization of flow rate measurement with help of sampling flowmeters" – edited (in Polish) by the Publishers of the Silesian University of Technology in 1997 and 2003. He is co-author of Polish Standard PN-M-42370: 1998 "Measurement of volumetric flow rate of fluids in closed conduits – Ultrasonic flowmeters" (in Polish).

Within the framework of TEMPUS program he investigated the sensor of vortex flowmeter in Ecole Supérieure de Physique et Chimie Industrielles de Paris in July 1996. He gives lectures on fundamentals of measurements and industrial measurements and is the co-author of 9 scripts and co-editor of one of them: "Laboratory of industrial measurements" – 1997. His main field of interest is modelling of sampling flowmeters and measurements of flow rate in closed conduits and in open channels. S. Waluś is a member of Polish Society of Sensor Technique, Polish Society of Metrology and Committee of Metrology of Katowice Branch of Polish Academy of Science. Since 1990 he is the secretary of this Committee.

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GAS CHROMATOGRAPHY