MASTER THESIS IN AUTOMATIC CONTROL 82/83

BJÖRN WITTENMARK

DEPARTMENT OF AUTOMATIC CONTROL
LUND INSTITUTE OF TECHNOLOGY

JANUARY 1984
# Title and subtitle
Master Theses in Automatic Control 82/83

## Abstract
The report contains abstracts of Master Theses (examensarbete) made of the Department of Automatic Control, Lund, during the academic year 82/83. During this year 23 theses were made by 25 students. Most of the theses are written in Swedish with an English abstract.

## Key words

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1. INTRODUCTION

The education for civilingenjörsexamen (Master Degree in Engineering) is completed with an independent work, the Master Thesis (examensarbete). It should show the student's ability to attack and solve a larger problem. The time devoted to the thesis is about three month of full time work. The thesis can be made individually or by two students together.

This report is a collection of the document pages of the theses completed during the academic year 1982/1983. During this time 23 theses were finished by 25 students. The major part of the theses is made within the framework of the research program at the department. Some of the theses are made as feasibility studies or in cooperation with the industry or other departments at the university.

Further information concerning the results can be obtained from the Department of Automatic Control by contacting the advisor. The theses may be borrowed through your library service or from the following libraries in Sweden:

Linköpings Universitetsbibliotek
Svenskttrycket, S-581 83 Linköping, Sweden

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Umeå Universitetsbibliotek
Box 718, S-901 10 Umeå, Sweden
2. LIST OF THESES


### 3. LIST OF SUBJECTS

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### 4. DOCUMENT PAGES

The following pages contain the document pages of the theses. Most of the theses are written in Swedish with only an abstract in English.
Digital algorithms for PI-control
(PI-algoritmer vid digital reglering)

Abstract
In this report a theoretical and an experimental investigation is made of different types of PI-algorithms in digital control. Four different ways to translate transfer functions from the Laplace- and to the 2-transform are investigated.
Six different programs for PI-controllers are presented, and are tested with different sample times and constants. The comparison is made for different types of transfer functions. Setting time, overshoots, static errors and "reset windups" are compared.

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**Title and subtitle**
Microcomputer-based data collection system for a margarine process
(Mätvärdesinsamling med mikrodator utförd på en margarinprocess)

**Abstract**
Following report describes a computerized measuring system based on the Swedish micro-computer ABC 80. The system was able to handle up to 30 measuring channels. Received measuring data was stored on a discette. The control of the system was carried out by a program in the computer. For analysis of the result, a few program was developed.
The system was applicable on a margarinemaking process and found out to have the desirable function.

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**Title and subtitle**

Three dimensional computer graphics and animation of an industrial robot (Tre dimensionell datografik och animering av industrirobot.)

**Abstract**

A three dimensional graphics package has been developed. It includes scan conversion of polyquous, hidden surface removal, shading and transformation of coordinate systems. It has been used for animation of an industrial robot. The movement of the robot is specified in a cartesian coordinate system using jousticks.

**Key words**

Computer graphics, robotics

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Control of variation in density of a fiberglass carpet.
(Styrning av fiberutläggning)

Abstract

The subject of this master thesis was originally proposed by the fiberglass company Gullfiber in Billsholm. The purpose of the assignment was to find methods to decrease and control the variation in density of a fiberglass insulating carpet. After a brief description of the process and the conditions for the further work we then compute the ideal frequency in relationship to the velocity of the receiving line. We then explain the measurements done to confirm the theory. With frequency analysis we can show that the wig-wag frequency is not very strong as distinct as frequencies of density variation. Instead the variation is more LF. Therefore we found a more probable cause for the variations in pressure variation.
Self-tuners based on gradient methods
(Självinställare baserade på gradientmetoder)

Abstract
The report presents a scheme for self-tuning regulators based on gradient methods. The feasibility of the scheme is studied in some special cases. The scheme is used together with different estimation techniques such as extended least squares (ELS) method and indirect estimation using a one to one correspondence with the regulator parameters.

The method is illustrated using simulations of two different processes.
A Selftuning PID-Controller For Systems with Timevarying Time delay
(En självinställande PID-regulator för system med variabel tidsfördröjning)

Abstract

A selftuning PID-controller is investigated. It is assumed that the process order is two. A pole-placement-algorithm is used to get the desired closed loop poles. Two methods are studied for the calculation of the control parameters. The first method is based on solving a system of equations. The second method makes a two-steps-estimation of the control parameters. The only a-priori knowledge of the process needed is, except the order, the maximum time delay. The two methods are compared using simulated systems. It is shown that the discussed controller can adapt to changes in the time delay.
Studies of Dissolved Oxygen Control in Biological Wastewater Treatment
(Studier av syre-reglering i biologisk avloppsrening)

Abstract
In this report, the dynamics of an aerator of an activated sludge process is studied. Two control strategies for the dissolved oxygen concentration are tested. One contains either a PI-controller or a on-off controller, the other a self-tuning controller.

There are two key-parameters in the system, \( K_{\text{La}} \), the total oxygen transfer rate, and \( \text{OUR} \), the oxygen uptake rate of the microorganisms in the aerator. The parameters are difficult to obtain from direct measurements. An estimator is derived. The estimates will be calculated from the process output, DO-concentration, and from the input signal, the air-flow rate.

The estimator is also part of a self-tuning controller. Here, the controller works with a minimum variance algorithm.

The simulations show, that the estimates contain a bias, if the estimation of the two parameters are done at the same time. Different methods are tested to avoid this problem. Even if bias cannot be avoided, the estimator can be used in a self-tuning controller because the total estimation error is close to zero. To obtain unbiased estimates of the two parameters is important in other aerator control schemes. Therefore different approaches have to be taken.

The simulations show that an acceptable control can be obtained both with a PI-controller and with a self-tuning controller.
This report describes a program for a linear-quadratic selftuner. It also includes results from experiments with the regulator. In the experiments different processes has been simulated on an analog computer. An important result from the experiments is that if an antialiasfilter is used when regulating a process, the dynamics of the the filter must be included in the processmodel. It is also necessary to take into account the time-delay in the regulator when using short sampling periods.

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A system for neutron flux monitoring is under development. It is based on Self-powered neutron detectors with cobalt emitter. The characteristic of this type of detector change, due to irradiation, and must be compensated for. A model based on the two domination components in the detector current has been developed. One component is proportional to thermal neutron flux and the quantity of the isotope $^{59}$Co in the emitter. The other is a not wanted background current caused by the beta-decaying isotope $^{60}$Co. To be able to make a correct compensation of the detector changes it is necessary to estimate the isotope quantities in the emitter. This is done by the computer in the system. The here described program calculates the new isotope quantities every twenty hour and has the capacity to administrate forty Self-Powered neutron detectors.

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Uppbyggnad av en digital bilhantering i ett svepelektronmikroskop. (Subroutines for taking up and displaying pictures from a computer controlled scanning-electron microscope (SEM)).

Abstract

The programs are made to decide testingpoints in an integrated circuit. The measurements on the IC are performed in a SEM using digital electronbeamdeflection and digital secondary-electron detection. A PDP11/23 computer and a QRGB-256 video-interface are used. Programs are written in MACRO-assembler and FORTRAN. Pictures may be taken up and stored on a massstorage (floppy-disk) for later retrieval. The picture image may be changed (color and displayingarea). Co-ordinates in the displayed pictures may be estimated with a joystickmovable cross. Also the picturearea may be moved with the joystick.

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Distribution: The report may be ordered from the Department of Automatic Control or borrowed through the University Library 2, Box 1010, S-221 03 Lund, Sweden, Telex: 33248 Lundis Lund.
Methods for automatic tuning of PID regulators

Abstract
A self-tuning PID-regulator has been investigated. The design method is based on the very well-known and simple Ziegler-Nichols self oscillation method. By introducing the describing function technique and by connecting a relay in the closed loop system, an oscillation is obtained automatically. It is noticed that this oscillation, whose amplitude is depending on the amplitude of the relay, has the same characteristics as the one, which is obtained manually by the Ziegler-Nichols self oscillation method, i.e. only proportional regulator is used and the oscillation is then obtained by increasing the gain gradually. Two methods, namely the peaks and zero-crossings method and the recursive least squares method, are proposed for estimating the amplitude and the frequency of the oscillation, in order to determine the critical gain and the ultimate period. The settings of the PID-regulator are then determined according to the tuning rules. The investigations have carried out first without any disturbance with four processes, and then only one of the four processes with measurement noise and load disturbance. Different levels of the measurement noise are used. A relay with hysteresis is used in order to make those methods for estimating the parameters less sensitive to the measurement noise. The problems of high frequency point of convergence and the level adjustment of the control signal have also been investigated. The results have shown that there is an advantage of using the relay with hysteresis and the self-tuner works quite well as a whole.
The goal of this work is to build a dynamic model for a scalemodel of a process with coupled drives, using frequency and step-response analysis and to construct a regulator for this model. The scale-model, constructed by the English company Tecquipment, is primarily intended for laboratory use by students.

The main problem is to reduce the interaction between the dynamics of the tension and the dynamics of the speed in the material which is transported between the DC-motors. This is solved by introducing a decoupling device in the regulator which makes it possible to control speed and tension with two independent control signals.

A model based on physical laws has been constructed and simulations have shown satisfactory resemblances to the real system.
During recent years, the application of electronic devices to road vehicles has grown tremendously. Increased environmental concern and requirements on fuel economy, comfort and safety have created a need for compact and advanced microcomputer technology.

A vehicle is a problematic environment for electronic devices due to dust, damp, vibrations, noise and glitches.

This report first gives an overview of electronic applications on road vehicles and concentrates later on truck and bus airbrake systems. Dynamic problems like delay, wheel lockning and load compensation are discussed.

A model of a feed back brake system that compensates for some of the delay and that can be combined with a load compensating and anti-skid system is derived and simulated.
Handbook for TA 6500 microprocessor control unit and investigation of some tuning rules for PI-controllers.

Abstract

This work contains two independent parts.

The first part is mainly a report on a documentation of a microprocessed control device called TA 6500, manufactured by Tour & Anderson AB.

The other part contains a documentation of an investigation concerning different adjustment rules for PI-controllers.
# Analysis and synthesis of the dynamics of an industrial robot.

## Title
Frequency analysis of the mechanical part of an ASEA industrial robot is performed. For the axis that limits the performance, the poles and zeros are calculated by means of curve fitting. An approach is made to design a speed regulator using polynomial synthesis. Due to the very high sensitivity of modelling errors the conclusion is that it is uncertain if the required rise time of 15-20 ms can be reached by using theories for sampled systems.

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A self-tuning controller for frequency control of power systems by HVDC.

One of the advantages of High Voltage Direct Current, HVDC, is the possibility to control the powerflow between different parts of an A.C. network. This property is being used when disturbances in the frequency, caused by load variations, is eliminated. Simulation studies on a physically scaled model of the "Gotland-transmission" has been done. Also a model of frequency oscillations between two connected power-areas is simulated on an analog computer.

The controller is based on the criterion to minimize the variance of the frequency deviation combined with the recursive method of least squares.
This thesis treats the ellipsoid method for linear programming. The method is described both from a theoretical and a practical point of view. A subroutine, LPEM, which solves LP-problems with the ellipsoid method, is presented and described. LPEM is written in Pascal. Finally some computational results from running LPEM on two test examples, Klee-Minty's problem and the double integrator controlled by the LP-regulator, are presented and discussed.
Abstract

This master thesis describes a mathematical model of a boiling water reactor and address the dynamic behaviour of the neutron kinetics, boiling dynamics and pressure stability.

The simulations have been done using the SIMNON-program.

The meaning were that the result from this work possibly would be adjust to supervision methods suitable for application in computer systems.

This master thesis in automatic control has been done at the Department of Automatic Control, Lund Institute of Technology. The initiative to the work came from Sydkraft AB. At the realization of the work, civ.ing. Sten Bergman, Sydkraft AB has been the instructor.
Abstract

This master thesis describes a Simmon model of a boiling water reactor to be used in simulating faults and disturbances. These faults and disturbances will be detected by noise analysis. Some methods in identification and noise analysis are also described and are applied on some malfunctions of a servo. A Pascal program for recursive parameter identification was also written and tested. This program is to be used in an expert system for noise analysis on the nuclear power plant Barsebäck.

Key words

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Distribution: The report may be ordered from the Department of Automatic Control or borrowed through the University Library 2, Box 1010, S-221 03 Lund, Sweden, Telex: 33248 lubbis lund.
In this report, the dynamics of a drying drum in a fertilizer industry have been studied, and a digital temperature controller have been designed.

A number of step responses were measured, to get an idea on how the process worked. From the step responses the conclusion were drawn that a cascades-controller, feedbacked from both the temperature into and out from the drying drum, would control the temperature sufficiently. To find the best parameter values two different strategies were used: the first one is to optimize the step response of the temperature and the other one is to simulate a physical model of the drying drum with a simulation-program.

For both the strategies a sampling-interval of one minute were used. The program was implemented in the computer and the controller were tested on the real process. The parameter values were adjusted and the final result was: \( K_p = 0.3 \), \( K_i = 31 \, ^\circ \text{C} \), \( T_1 = 8.5 \) minutes.

Although the simulation were made with a rough physical model, its parameter values were much closer to the final ones than the values from the optimization. This shows that one can get good results even with a simple model. However, it is not always that easy to put up a physical model.

In the last chapter the control system has been examined. The meaning is, to show how a working system in industry can look like, and to show how the actual control design is put into the computer.
Title and subtitle
Controlled peroxide level in a microbial process.
(Reglerad peroxidmiljö i en mikrobiell process.)

Abstract
Consumption of oxygen in microbial processes is often rapid and in dense cultures the supply of oxygen might be limiting. Conventional aeration, e.g. agitation, is not possible when using immobilized cells due to the low mechanical stability of the preparations. The acetic acid bacteria *Gluconobacter oxydans* catalyses the conversion of glycerol to dihydroxyacetone and the decomposition of hydrogen peroxide to oxygen. Oxygen is necessary for the first conversion and consequently hydrogen peroxide might be used as an oxygen source in a process for production of dihydroxyacetone.

However, hydrogen peroxide is toxic to microorganisms and thus a controller addition based on measured peroxide-concentration is necessary. A PI-controller and a controller using a Kalman filter are tested on the process. Reaction rate and viability tests gives information about the cell functions. Two different processes have been investigated, one utilizing immobilized cells and one system with membrane reactors.

Key words
Abstract

Self Tuning Regulators are regarded from a practical point of view. Different problems and some of the solutions to the problems are discussed based on experiences from laboratory experiments.

Praktiska aspekter på självinställande regulatorer behandlas. Olika problem och en del förslag till lösningar av dem diskuteras med utgångspunkt från försök med en labprocess.
A method of design for multivariable systems is presented. It is used in an application design of a controller for an advanced aircraft. The main design criteria, singular values plot, is discussed in detail. A must for the use of the method is that computer assistance is available. Two different interactive program packages allowing LQG-design are presented and somewhat compared.