PREDICTIVE CONTROL APPLIED FOR LINEAR AND NONLINEAR PLANTS

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INTRODUCTION

Predictive control algorithms emerged in the middle of the seventies from the side of industrial applications. The main idea was to develop robust control algorithms based on simple, measurable process models, providing acceptable results also with constraints, noises and parameter uncertainties. These algorithms, using predicted future information could provide better control performance compared to the usual PID control especially in case of known reference signal and with big dead time in the plant. The philosophy behind is that using more information better decisions could be done. The main idea is to calculate the actual and the subsequent control signals minimising the quadratic deviation of the reference signal and the output signal in a given future horizon. According to the receding horizon control strategy only the first control signal is used at the process input, and in the next sampling point the procedure is repeated. Theoretical analysis of different versions of predictive control followed the presentation of the first successful industrial applications. Nowadays it is declared that predictive control algorithms are the secondly most used algorithms in the process industry – besides PID control. Predictive control algorithms have been developed mainly for linear plants. Predictive control seems to be a promising technique also in nonlinear environment. This is a strong research direction.

The aim of the course is to give an introduction to predictive control. Predictive control idea is explained, its connection to other control methods is given. Different versions of predictive control algorithms are discussed and the effects of the tuning parameters are analysed. Handling of constraints and some robustness issues are also dealt with. Laboratory exercises using MATLAB/SIMULINK environment demonstrate the behaviour of the algorithms.

LECTURERS

The course material has been prepared by associate prof. Ruth Bars and prof. Robert Haber.
Ruth Bars will present the lectures.

CONTENTS

1.3.2. PID, LQ, predictive, etc.

1.4 Handling of constraints

1.5 Adaptive control, robust control (just the conceptions)

Robustness versus adaptivity

1.6 Software aids

MATLAB/SIMULINK, toolboxes.

1.7 **Computer Laboratory I.**

Examples, tasks, homework.

Framework of different control structures is given with SIMULINK block diagrams. Design PID controllers for a given plant with significant dead time in feedback, feedforward, cascade and IMC structure. Analyse the tracking and noise rejection properties. Observe that dead time gives limitation for the settling time.

2. Predictive control idea

2.1 Predictive control concept

The cost function

Receding horizon strategy

The tuning parameters

2.2 Long-range predictive control, extended horizon predictive control

2.3 Relation to the LQ problem

3. Process models

Each controller is designed considering a process model.

3.1 About physical models. Linear and nonlinear models. Grey box, black box, identification

3.2 Examples (e.g. water tank, DC motor)

3.3 LS method to determine the parameters

3.3.1. The off-line LS method

3.3.2. Recursive LS estimation

3.3.3. Examples

3.3.4. Some problems in the design of identification experiments.

3.4 **Computer laboratory II.**

Building up models of systems in SIMULINK (e.g. two tank model, DC motor model)

Linearization.

Analysing their step response.

Identification of the parameters, off-line and on-line identification using MATLAB identification toolbox.

4. Linear models for predictive control

Predictive control is based on a predictive process model.

The conception of the free and forced responses.

4.1 Nonparametric models, input-output approaches

4.1.1. Weighting function.

Predictive equations. Separation of the effect of the past, the actual and future control actions to the future response.

4.1.2. Unit-step response. Predictive equations.

4.1.3. Estimation of the noise with IMC structure.

4.2 Parametric models, input-output approaches

4.2.1. Pulse transfer function

4.2.2. Noise models. ARMA, ARIMA, etc. models.

4.2.3. Relationship with the weighting function model and the unit-step response

4.2.4. Predictive transformation

4.2.5. Incremental transformation

4.2.6. Relationship between the predictive transformation and the weighting function points

4.2.7. *Demonstration*: a JAVA applet showing the meaning of the free and forced response

4.3 State-space models. Predictive forms.

5. Predictive control algorithms for linear systems

5.1 The cost function

5.2 Model-algorithmic control (MAC)

5.3 Dynamic matrix control (DMC)

5.4 Generalized predictive control (GPC)

5.5 GPC with end-point state weighting
5.6 Long-range and extended horizon control algorithms
5.7 Predictive control algorithms based on state space representation
5.8 Control strategies
5.9 Guidelines for tuning of the parameters
5.10 Handling of constraints
5.11 **Computer laboratory III.**
GPC control of linear plants. Simulation examples using a MATLAB program. Analyse the effect of the different strategies and of the tuning parameters. Evaluate the results. Compare the results with PID and LQ control.

6. Predictive control of MIMO systems

7. Some aspects of adaptive predictive control

7.1 **Computer laboratory IV.**
Adaptive GPC control of linear plants.

8. Some classes of nonlinear models

8.1 Nonparametric models
8.1.1. Nonparametric Hammerstein model
8.1.2. Nonparametric Volterra model
8.2 Parametric models
8.2.1. Simple Hammerstein model
8.2.2. Generalized Hammerstein model
8.2.3. Simple Wiener model
8.2.4. Generalized Wiener model
8.2.5. Volterra model
8.2.6. Bilinear model
8.2.7. Predictive incremental transformation of the models

8.3 Computer laboratory V.
Identification and predictive control of a two tank model

9. Predictive control algorithms for some classes of nonlinear systems

9.1 Predictive control of the parametric generalized Hammerstein and Volterra model
Long-range and extended horizon algorithms
The effect of the control strategies and of the tuning parameters
Simulation examples.
Demonstration of the linearization effect of the algorithms

10. Industrial applications

Case studies. Industrial applications on the basis of the literature.

11. Summary

12. References

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Selected papers on predictive control
Report by R. Haber and R. Bars