

Contents

1 Introduction to Advanced Process Control Concepts	1
1.1 Process Time Constant.....	1
1.2 Domain Transformations	3
1.3 Laplace Transformation	5
1.4 Discrete Approximations	7
1.5 z-Transforms	9
1.6 Advanced and Modified z-Transforms	13
1.7 Common Elements in Control	16
1.8 The Smith Predictor	18
1.9 Feed-forward Control	21
1.10 Feed-forward Control in a Smith Predictor.....	23
1.11 Dahlin's Control Algorithm.....	26
References	31
2 Process Simulation.....	33
2.1 Simulation using Matlab Simulink	33
2.2 Simulation of Feed-forward Control.....	37
2.3 Control Simulation of a 2x2 System.....	39
2.4 Simulation of Dahlin's Control Algorithm	43
3 Process Modeling and Identification.....	45
3.1 Model Applications.....	45
3.2 Types of Models	46
3.2.1 White Box and Black Box Models	46
3.2.2 Linear and Non-linear Models.....	48
3.2.3 Static and Dynamic Models.....	48
3.2.4 Distributed and Lumped Parameter Models	48
3.2.5 Continuous and Discrete Models.....	49
3.3 Empirical (linear) Dynamic Models	50
3.4 Model Structure Considerations	50
3.4.1 Parametric Models.....	52
3.4.2 Non-parametric Models.....	54
3.5 Model Identification	57
3.5.1 Introduction	57
3.5.2 Identification of Parametric Models	57
3.5.3 Identification of Non-parametric Models	69
References	70

4 Identification Examples	73
4.1 SISO Furnace Parametric Model Identification	73
4.2 MISO Parametric Model Identification	79
4.3 MISO Non-parametric Identification of a Non-integrating Process	83
4.4 MIMO Identification of an Integrating and Non-integrating Process	85
4.5 Design of Plant Experiments	88
4.5.1 Nature of Input Sequence	88
4.5.2 PRBS Type Input	89
4.5.3 Step Type Input	90
4.5.4 Type of Experiment	91
4.6 Data File Layout	92
4.7 Conversion of Model Structures	92
4.8 Example and Comparison of Open and Closed Loop Identification	97
References	102
5 Linear Multivariable Control.....	103
5.1 Interaction in Multivariable Systems	103
5.1.1 The Relative Gain Array	103
5.1.2 Properties of the Relative Gain Array	104
5.1.3 Some Examples	105
5.1.4 The Dynamic Relative Gain Array	107
5.2 Dynamic Matrix Control.....	108
5.2.1 Introduction	108
5.2.2 Basic DMC Formulation	108
5.2.3 One Step DMC	112
5.2.4 Prediction Equation and Unmeasurable Disturbance Estimation	115
5.2.5 Restriction of Excessive Moves	116
5.2.6 Expansion of DMC to Multivariable Problems	118
5.2.7 Equal Concern Errors	119
5.2.8 Constraint Handling	120
5.2.9 Constraint Formulation	121
5.3 Properties of Commercial MPC Packages	124
References	126
6 Multivariable Optimal Constraint Control Algorithm	127
6.1 General Overview	127
6.2 Model Formulation for Systems with Dead Time	129
6.3 Model Formulation for Multivariable Processes	130
6.4 Model Formulation for Multivariable Processes with Time Delays	132
6.5 Model Formulation in Case of a Limited Control Horizon.....	132
6.6 Mokka Control Formulation.....	133
6.7 Non-linear Transformations.....	134
6.8 Practical Implementation Guidelines.....	135
6.9 Case Study	136
6.10 Control of a Fluidized Catalytic Cracker	140
6.11 Examples of Case Studies in MATLAB	144

6.12 Control of Integrating Processes	148
6.13 Lab Exercises	150
6.14 Use of MCPC for Constrained Multivariable Control	156
References	159
7 Internal Model Control.....	161
7.1 Introduction.....	161
7.2 Factorization of Multiple Delays	162
7.3 Filter Design	164
7.4 Feed-forward IMC	164
7.5 Example of Controller Design	165
7.6 LQ Optimal Inverse Design.....	167
References	168
8 Nonlinear Multivariable Control	171
8.1 Non-linear Model Predictive Control	171
8.2 Non-linear Quadratic DMC	174
8.3 Generic Model Control	176
8.3.1 Basic Algorithm	176
8.3.2 Examples of the GMC Algorithm	179
8.3.3. The Differential Geometry Concept.....	179
8.4 Problem Description	181
8.4.1 Model Representation.....	181
8.4.2 Process Constraints.....	182
8.3.3 Control Objectives.....	184
8.5 GMC Application to the CSTR System.....	186
8.5.1 Relative Degree of the CSTR System	186
8.5.2 Cascade Control Algorithm.....	187
8.6 Discussion of the GMC Algorithm	188
8.7 Simulation of Reactor Control	188
8.8 One Step Reference Trajectory Control.....	193
8.9 Predictive Horizon Reference Trajectory Control	195
References	198
9 Optimization of Process Operation.....	201
9.1 Introduction to Real-time Optimization	201
9.1.1 Optimization and its Benefits	201
9.1.2 Hierarchy of Optimization.....	202
9.1.3 Issues to be Addressed in Optimization	204
9.1.4 Degrees of Freedom Selection for Optimization	206
9.1.5 Procedure for Solving Optimization Problems.....	207
9.1.6 Problems in Optimization.....	208
9.2 Model Building.....	209
9.2.1 Phases in Model Development	210

9.2.2 Fitting Functions to Empirical Data	211
9.2.3 The Least Squares Method	213
9.3 The Objective Function	216
9.3.1 Function Extrema	216
9.3.2 Conditions for an Extremum	217
9.4 Unconstrained Functions: one Dimensional Problems	218
9.4.1 Newton's Method	218
9.4.2 Quasi-Newton Method	219
9.4.3 Polynomial Approximation	219
9.5 Unconstrained Multivariable Optimization	219
9.5.1 Introduction	219
9.5.2 Newton's Method	221
9.6 Linear Programming	222
9.6.1 Example	222
9.6.2 Degeneracies	224
9.5.3 The Simplex Method	225
9.6.4 The Revised Simplex Method	229
9.6.5 Sensitivity Analysis	230
9.7 Non-linear Programming	231
9.7.1 The Lagrange Multiplier Method	231
9.7.2 Other Techniques	232
9.7.3 Hints for Increasing the Effectiveness of NLP Solutions	232
References	233
10 Optimization Examples	235
10.1 AMPL: a Multi-purpose Optimizer	235
10.1.1 Example of an Optimization Problem	235
10.1.2 AMPL Formulation of the Problem	237
10.1.3 General Structure of an AMPL Model	237
10.1.4 General AMPL Rules	238
10.1.5 Detailed Review of the Transportation Example	239
10.2 Optimization Examples	243
10.2.1 Optimization of a Separation Train	243
10.2.2 A Simple Blending Problem	246
10.2.3 A Simple Alkylation Reactor Optimization	248
10.2.4 Gasoline Blending	251
10.2.5 Optimization of a Thermal Cracker	253
10.2.6 Steam Net Optimization	257
10.2.7 Turbogenerator Optimization	260
10.2.8 Alkylation Plant Optimization	263
References	268
11 Integration of Control and Optimization	273
11.1 Introduction	273
11.2 Description of the Desalination Plant	273
11.3 Production Maximization of Desalination Plant	274

11.4 Linear Model Predictive Control of Desalination Plant.....	276
11.5 Reactor problem definition	279
11.6 Multivariable Non-linear Control of the Reactor	282
References	284
Appendix I. MCPC software guide	285
I.1 Installation	285
I.2 Model identification	285
I.2.1 General process information	286
I.2.2 Identification data	286
I.2.3 Output details	287
I.3 Controller design	289
I.4 Control simulation	291
I.5 Dealing with constraints	293
I.6 Saving a project	294
Appendix II. Comparison of control strategies for a hollow shaft reactor..	295
II.1 Introduction	295
II.2 Model Equations	295
II.3 Proportional Integral Control	299
II.4 Linear Multivariable Control	300
II.5 Non-linear Multivariable Control	302
References	304

<http://www.springer.com/978-3-540-40480-4>

Advanced Practical Process Control

Roffel, B.; Betlem, B.

2004, IX, 309 p. With online files/update., Hardcover

ISBN: 978-3-540-40480-4