

- Preface p. xi
- Contributors p. xiii
- Part I p. 1
- 1 Review of nonlinear model predictive control applications T.A. Badgwell and S.J. Qin p. 3
 - 1.1 Introduction p. 3
 - 1.2 Theoretical foundations of NMPC p. 6
 - 1.3 Industrial implementations of NMPC p. 9
 - 1.3.1 Models p. 9
 - 1.3.2 Output feedback p. 15
 - 1.3.3 Steady-state optimisation p. 15
 - 1.3.4 Dynamic optimisation p. 16
 - 1.3.5 Constraint formulations p. 16
 - 1.3.6 Output trajectories p. 17
 - 1.3.7 Output horizon and input parameterisation p. 18
 - 1.3.8 Solution methods p. 19
 - 1.4 NMPC application examples p. 19
 - 1.4.1 PFC: application to batch reactors p. 20
 - 1.4.2 Aspen Target: application to a pulverised coal fired boiler p. 20
 - 1.4.3 MVC: application to an ammonia plant p. 21
 - 1.4.4 NOVA-NLC: application to a polymerisation process p. 22
 - 1.4.5 Process Perfecter: application to a polypropylene process p. 24
 - 1.5 Future needs for NMPC technology development p. 27
 - 1.5.1 Model development p. 27
 - 1.5.2 Output feedback p. 28
 - 1.5.3 Optimisation methods p. 28
 - 1.5.4 User interface p. 29
 - 1.5.5 Justification of NMPC p. 29
 - 1.5.6 Other issues p. 29
 - 1.6 Conclusions p. 29
 - 1.7 References p. 30
 - 1.8 Notes p. 32
- 2 Nonlinear model predictive control: issues and applications R.S. Parker and E.P. Gatzke and R. Mahadevan and E.S. Meadows and F.J. Doyle III p. 33
 - 2.1 Introduction p. 33
 - 2.2 Exploiting model structure p. 34
 - 2.2.1 Motivation p. 34
 - 2.2.2 Model identification p. 35
 - 2.2.3 Controller synthesis p. 36
 - 2.2.4 Application: a continuous bioreactor p. 38
 - 2.3 Efficient dynamic optimisation using differential flatness p. 39
 - 2.3.1 Motivation p. 39
 - 2.3.2 Problem formulation p. 40
 - 2.3.3 Application: biomass optimisation p. 41
 - 2.4 Model-based control of population balance systems p. 43

- 2.4.1 Motivation: emulsion polymerisation p. 43
- 2.4.2 Model development p. 44
- 2.4.3 Numerical solutions of the population balance equation p. 45
- 2.4.4 Approaches to control p. 45
- 2.4.5 Measurement and feedback p. 46
- 2.4.6 Batch polymerisation example p. 47
- 2.5 Disturbance estimation p. 48
- 2.5.1 Motivation p. 48
- 2.5.2 Estimation formulation p. 49
- 2.5.3 Application: chemical reactor disturbance estimation p. 51
- 2.6 Conclusions p. 51
- 2.7 Acknowledgments p. 53
- 2.8 References p. 53
- 2.9 Notes p. 57
- Part II p. 59
- 3 Model predictive control: output feedback and tracking of nonlinear systems L. Magni and G. De Nicolao and R. Scattolini
- 3.1 Introduction p. 61
- 3.2 Preliminaries and state-feedback control p. 63
- 3.3 Output feedback p. 66
- 3.4 Tracking and disturbance rejection for signals generated by an exosystem p. 68
- 3.5 Tracking 'asymptotically' constant references p. 72
- 3.5.1 State-space models p. 73
- 3.5.2 Nonlinear ARX models p. 75
- 3.6 Conclusions p. 77
- 3.7 Acknowledgment p. 77
- 3.8 References p. 78
- 4 Model predictive control of nonlinear parameter varying systems via receding horizon control Lyapunov functions M. Szaier and J. Cloutier p. 81
- 4.1 Introduction p. 81
- 4.2 Preliminaries p. 84
- 4.2.1 Notation and definitions p. 84
- 4.2.2 Quadratic regulator problem for NLPV systems p. 85
- 4.3 Equivalent finite horizon regulation problem p. 86
- 4.4 Modified receding horizon controller p. 89
- 4.5 Selecting suitable CLFs p. 91
- 4.5.1 Autonomous systems p. 92
- 4.5.2 Linear parameter varying systems p. 93
- 4.6 Connections with other approaches p. 96
- 4.7 Incorporating constraints p. 97
- 4.8 Illustrative examples p. 98
- 4.9 Conclusions p. 103
- 4.10 Acknowledgments p. 103
- 4.11 References p. 103

- 4.12 Appendix: SDRE approach to nonlinear regulation p. 105
- 5 Nonlinear model-algorithmic control for multivariable nonminimum-phase processes M. Niemiec and C. Kravaris p. 107
 - 5.1 Introduction p. 107
 - 5.2 Preliminaries p. 109
 - 5.2.1 Relative order p. 110
 - 5.2.2 Zero dynamics and minimum-phase behaviour p. 111
 - 5.3 Brief review of nonlinear model-algorithmic control p. 112
 - 5.4 Model-algorithmic control with nonminimum-phase compensation using synthetic outputs p. 114
 - 5.5 Construction of statically equivalent outputs with pre-assigned transmission zeros p. 116
 - 5.5.1 Construction of independent functions which vanish on the equilibrium manifold p. 117
 - 5.5.2 A class of statically equivalent outputs p. 119
 - 5.5.3 Assignment of transmission zeros p. 120
 - 5.6 Application: control of a nonminimum-phase chemical reactor p. 122
 - 5.7 Conclusion p. 128
 - 5.8 References p. 128
 - 5.9 Appendix p. 129
 - 5.9.1 Proof of Proposition 1 p. 129
 - 5.9.2 Proof of Lemma 1 p. 130
- 6 Open-loop and closed-loop optimality in interpolation MPC M. Cannon and B. Kouvaritakis p. 131
 - 6.1 Introduction p. 131
 - 6.2 Problem statement p. 132
 - 6.3 Predicted input/state trajectories p. 133
 - 6.3.1 Unconstrained optimal control law $u^{[o]}$ p. 134
 - 6.3.2 Feasible control law $u^{[f]}$ p. 136
 - 6.4 Interpolation MPC algorithms p. 138
 - 6.4.1 Comparison of open-loop optimality p. 140
 - 6.4.2 Closed-loop optimality properties p. 141
 - 6.5 Simulation example p. 145
 - 6.6 Conclusions p. 148
 - 6.7 Acknowledgment p. 148
 - 6.8 References p. 149
- Part III p. 151
- 7 Closed-loop predictions in model based predictive control of linear and nonlinear systems B. Kouvaritakis and J.A. Rossiter and M. Cannon p. 153
 - 7.1 Introduction p. 153
 - 7.2 Review of earlier work p. 155
 - 7.3 MPC for linear uncertain systems p. 158
 - 7.4 Invariance/feasibility for nonlinear systems p. 161
 - 7.5 Numerical examples p. 165
 - 7.5.1 Application of Algorithm 1 p. 165
 - 7.5.2 Application of Algorithm 2 p. 167

- 7.6 Acknowledgment p. 171
- 7.7 References p. 171
- 8 Computationally efficient nonlinear predictive control algorithm for control of constrained nonlinear systems A. Zheng and Wei-hua Zhang p. 173
- 8.1 Introduction p. 173
- 8.2 Preliminaries p. 175
- 8.3 Computationally efficient algorithm p. 177
- 8.4 Examples p. 179
- 8.4.1 Distillation dual composition control p. 179
- 8.4.2 Tennessee-Eastman problem p. 181
- 8.5 Conclusions p. 184
- 8.6 Acknowledgment p. 184
- 8.7 References p. 185
- 9 Long-prediction-horizon nonlinear model predictive control M. Soroush and H.M. Soroush p. 189
- 9.1 Introduction p. 189
- 9.2 Scope and preliminaries p. 191
- 9.3 Optimisation problem: model predictive control law p. 191
- 9.4 Nonlinear feedforward/state feedback design p. 192
- 9.5 Nonlinear feedback controller design p. 194
- 9.6 Application to linear processes p. 195
- 9.7 Conclusions p. 197
- 9.8 Acknowledgments p. 197
- 9.9 References p. 197
- 9.10 Appendix p. 198
- 9.10.1 Proof of Theorem 1 p. 198
- 9.10.2 Proof of Theorem 2 p. 200
- Part IV p. 203
- 10 Nonlinear control of industrial processes B.A. Ogunnaike p. 205
- 10.1 Introduction p. 205
- 10.2 Applying nonlinear control to industrial processes p. 206
- 10.2.1 Quantitative needs assessment p. 207
- 10.2.2 Technological and implementation issues p. 208
- 10.3 Model predictive control of a spent acid recovery converter p. 209
- 10.3.1 The process p. 209
- 10.3.2 Process operation objectives p. 210
- 10.3.3 A control perspective of the process p. 211
- 10.3.4 Overall control strategy p. 212
- 10.3.5 Process model development p. 214
- 10.3.6 Control system design and implementation p. 215
- 10.3.7 Control system performance p. 216
- 10.4 Summary and conclusions p. 219
- 10.5 Acknowledgment p. 220
- 10.6 References p. 220

- 11 Nonlinear model based predictive control using multiple local models S. Townsend and G.W. Irwin p. 223
- 11.1 Introduction p. 224
- 11.2 Local model networks p. 225
- 11.3 Nonlinear model based predictive control p. 228
- 11.3.1 Local controller generalised predictive control (LC-GPC) p. 229
- 11.3.2 Local model generalised predictive control (LM-GPC) p. 230
- 11.4 Application p. 232
- 11.4.1 pH neutralisation pilot plant p. 232
- 11.4.2 Identification p. 232
- 11.4.3 Control p. 234
- 11.5 Discussion and conclusions p. 238
- 11.6 References p. 241
- 12 Neural network control of a gasoline engine with rapid sampling B. Lennox and G. Montague p. 245
- 12.1 Introduction p. 245
- 12.2 Artificial neural networks p. 246
- 12.3 ANN engine model development p. 248
- 12.4 Neural network based control p. 250
- 12.4.1 Application of the ANN model based controller to the gasoline engine p. 252
- 12.5 Conclusions p. 253
- 12.6 References p. 254
- Index p. 257