

Contents

1	Introduction	1
1.1	Classical MPC	4
1.2	Robust MPC	5
1.3	Stochastic MPC	7
1.4	Concluding Remarks and Comments on the Intended Readership	9
	References	9
 Part I Classical MPC		
2	MPC with No Model Uncertainty	13
2.1	Problem Description	13
2.2	The Unconstrained Optimum	15
2.3	The Dual-Mode Prediction Paradigm	18
2.4	Invariant Sets	21
2.5	Controlled Invariant Sets and Recursive Feasibility	24
2.6	Stability and Convergence	29
2.7	Autonomous Prediction Dynamics	32
	2.7.1 Polytopic and Ellipsoidal Constraint Sets	33
	2.7.2 The Predicted Cost and MPC Algorithm	36
	2.7.3 Offline Computation of Ellipsoidal Invariant Sets	38
2.8	Computational Issues	42
2.9	Optimized Prediction Dynamics	46
2.10	Early MPC Algorithms	51
2.11	Exercises	57
	References	62
 Part II Robust MPC		
3	Open-Loop Optimization Strategies for Additive Uncertainty	67
3.1	The Control Problem	68
3.2	State Decomposition and Constraint Handling	71

3.2.1	Robustly Invariant Sets and Recursive Feasibility.	73
3.2.2	Interpretation in Terms of Tubes	76
3.3	Nominal Predicted Cost: Stability and Convergence	83
3.4	A Game Theoretic Approach	86
3.5	Rigid and Homothetic Tubes	95
3.5.1	Rigid Tube MPC	96
3.5.2	Homothetic Tube MPC	101
3.6	Early Robust MPC for Additive Uncertainty	105
3.6.1	Constraint Tightening	105
3.6.2	Early Tube MPC	108
3.7	Exercises.	112
	References	119
4	Closed-Loop Optimization Strategies for Additive Uncertainty	121
4.1	General Feedback Strategies	122
4.1.1	Active Set Dynamic Programming for Min-Max Receding Horizon Control.	130
4.1.2	MPC with General Feedback Laws	137
4.2	Parameterized Feedback Strategies	145
4.2.1	Disturbance-Affine Robust MPC	146
4.2.2	Parameterized Tube MPC	153
4.2.3	Parameterized Tube MPC Extension with Striped Structure.	164
	References	172
5	Robust MPC for Multiplicative and Mixed Uncertainty	175
5.1	Problem Formulation	176
5.2	Linear Matrix Inequalities in Robust MPC.	178
5.2.1	Dual Mode Predictions	184
5.3	Prediction Dynamics in Robust MPC	187
5.3.1	Prediction Dynamics Optimized to Maximize the Feasible Set	192
5.3.2	Prediction Dynamics Optimized to Improve Worst-Case Performance.	198
5.4	Low-Complexity Polytopes in Robust MPC.	202
5.4.1	Robust Invariant Low-Complexity Polytopic Sets.	202
5.4.2	Recursive State Bounding and Low-Complexity Polytopic Tubes.	207
5.5	Tubes with General Complexity Polytopic Cross Sections	213
5.6	Mixed Additive and Multiplicative Uncertainty	223
5.7	Exercises.	233
	References	238

Part III Stochastic MPC

6 Introduction to Stochastic MPC 243

6.1 Problem Formulation 245

6.2 Predicted Cost and Unconstrained Optimal Control Law 251

6.3 Mean-Variance Predicted Cost 257

6.4 Early Stochastic MPC Algorithms 260

6.4.1 Auto-Regressive Moving Average Models. 260

6.4.2 Moving Average Models. 263

6.5 Application to a Sustainable Development Problem 264

References 268

7 Feasibility, Stability, Convergence and Markov Chains 271

7.1 Recursive Feasibility. 272

7.2 Prototype SMPC Algorithm: Stability and Convergence 278

7.2.1 Expectation Cost 278

7.2.2 Mean-Variance Cost. 281

7.2.3 Supermartingale Convergence Analysis. 284

7.3 Probabilistically Invariant Ellipsoids 286

7.4 Markov Chain Models Based on Tubes with Polytopic
Cross Sections 292

References 301

8 Explicit Use of Probability Distributions in SMPC. 303

8.1 Polytopic Tubes for Additive Disturbances 304

8.2 Striped Prediction Structure with Disturbance
Compensation in Mode 2 311

8.3 SMPC with Bounds on Average Numbers of Constraint
Violations 316

8.4 Stochastic Quadratic Bounds for Additive Disturbances. 319

8.5 Polytopic Tubes for Additive and Multiplicative Uncertainty . . . 328

References 340

9 Conclusions 343

Solutions to Exercises 347

Index 377



<http://www.springer.com/978-3-319-24851-6>

Model Predictive Control

Classical, Robust and Stochastic

Kouvaritakis, B.; Cannon, M.

2016, XIII, 384 p. 54 illus., 3 illus. in color. With online files/update., Hardcover

ISBN: 978-3-319-24851-6