# Contents

**Preface** . . . . . ix

**Introduction and Motivations** . . . . . xi

**Chapter 1. Metaheuristics for Controller Optimization** . . . . . 1

1.1. Introduction . . . . . 1
1.2. Evolutionary approaches using differential evolution . . . . . 2
1.2.1. Standard version . . . . . 2
1.2.2. Perturbed version . . . . . 7
1.3. Swarm approaches . . . . . 8
1.3.1. Particle swarm optimization algorithm . . . . . 8
1.3.2. Quantum particle swarm algorithm . . . . . 14
1.3.3. Artificial bee colony optimization algorithm . . . . . 20
1.3.4. Cuckoo search algorithm . . . . . 25
1.3.5. Firefly algorithm . . . . . 31
1.4. Summary . . . . . 33

**Chapter 2. Reformulation of Robust Control Problems for Stochastic Optimization** . . . . . 35

2.1. Introduction . . . . . 35
2.2. $H_\infty$ synthesis . . . . . 35
2.2.1. Full $H_\infty$ synthesis . . . . . 35
2.2.2. Fixed-structure $H_\infty$ synthesis . . . . . 45
2.2.3. Formulating $H_\infty$ synthesis for stochastic optimization . . . . . 67
2.2.4. Conclusion . . . . . 105

2.3. µ-Synthesis . . . . . 105
2.3.1. The problem of performance robustness . . . . . 105
2.3.2. µ-Synthesis . . . . . 110
2.4. LPV/LFT synthesis . . . . . 140
2.4.1. Introduction . . . . . 140
2.4.2. The LPV/LFT controller synthesis problem . . . . . 141
2.4.3. Reformulation for stochastic optimization . . . . . 147

**Chapter 3. Optimal Tuning of Structured and Robust $H_\infty$ Controllers Against High-level Requirements** . . . . . 171

3.1. Introduction and motivations . . . . . 171
3.2. Loop-shaping $H_\infty$ synthesis . . . . . 180
3.2.1. Approach principle . . . . . 180
3.2.2. Generalized gain and phase margins . . . . . 184
3.2.3. Four-block interpretation of the method . . . . . 185
3.2.4. Practical implementation . . . . . 186
3.2.5. Implementation of controllers . . . . . 190
3.3. A generic method for the declination of requirements . . . . . 194
3.3.1. General principles . . . . . 194
3.3.2. Special cases . . . . . 196
3.3.3. Management of requirement priority level . . . . . 197
3.4. Optimal tuning of weighting functions . . . . . 198
3.4.1. Optimization on nominal plant . . . . . 198
3.4.2. Multiple plant optimization . . . . . 202
3.4.3. Applicative example – inertial stabilization of line of sight . . . . . 207
3.5. Optimal tuning of the fixed-structure and fixed-order final controller . . . . . 238
3.5.1. Introduction . . . . . 238
3.5.2. Toward eliminating weighting functions . . . . . 240
3.5.3. Extensions to the approach . . . . . 259
3.5.4. Link with standard control problems . . . . . 277

**Chapter 4. *HinfStoch*: A Toolbox for Structured and Robust Controller Computation Based on Stochastic Optimization** . . . . . 279

4.1. Introduction . . . . . 279
4.2. Structured multiple plant H∞ synthesis . . . . . 280
4.2.1. Principle . . . . . 280
4.2.2. Formalism . . . . . 280

4.3. Structured μ-synthesis . . . . . 284
4.3.1. Principle . . . . . 284
4.3.2. Formalism . . . . . 285
4.4. Structured LPV/LFT synthesis . . . . . 288
4.4.1. Principle . . . . . 288
4.4.2. Formalism . . . . . 289
4.5. Structured and robust synthesis against high-level requirements with *HinfStoch_ControllerTuning* . . . . . 292
4.5.1. Principle . . . . . 292
4.5.2. Formalism . . . . . 293
4.5.3. Examples . . . . . 311

**Appendices** . . . . . 351

**Appendix A. Notions of Coprime Factorizations** . . . . . 353

**Appendix B. Examples of LFT Form Used for Uncertain Systems** . . . . . 359

**Appendix C. LFT Form Use of an Electromechanical System with Uncertain Flexible Modes** . . . . . 365

**Appendix D. FTM (1D) Computation from a Time Signal** . . . . . 383

**Appendix E. Choice of Iteration Number for CompLeib Tests** . . . . . 385

**Appendix F. PDE versus DE** . . . . . 393

**Bibliography** . . . . . 399

**Index** . . . . . 407