Contents

Preface ix

Introduction xiii

Chapter 1. Optimization: Theoretical Foundations and Methods 1

1.1. The formalization of an optimization problem 1
1.2. Constrained optimization methods 5
1.2.1. The method of Lagrange multipliers 9
1.2.2. Method of the quadratic penalization 11
1.2.3. Methods of interior penalties 12
1.2.4. Methods of exterior penalties 13
1.2.5. Augmented Lagrangian method 14
1.3. Classification of optimization methods 15
1.3.1. Deterministic methods 16
1.3.2. Stochastic methods 18
1.4. Conclusion 21
1.5. Bibliography 22

Chapter 2. Metaheuristics for Robotics 27

2.1. Introduction 27
2.2. Metaheuristics for trajectory planning problems 28
2.2.1. Path planning 29
2.2.2. Trajectory generation 43

2.3. Metaheuristics for automatic control problems 45
2.4. Conclusion 50
2.5. Bibliography 50

Chapter 3. Metaheuristics for Constrained and Unconstrained Trajectory Planning 53

3.1. Introduction 53
3.2. Obstacle avoidance 54
3.3. Bilevel optimization problem 58
3.4. Formulation of the trajectory planning problem 59
3.4.1. Objective functions 60
3.4.2. Constraints 62
3.5. Resolution with a bigenetic algorithm 63
3.6. Simulation with the model of the Neuromate robot 66
3.6.1. Geometric model of the Neuromate robot 67
3.6.2. Kinematic model of the Neuromate robot 71
3.6.3. Simulation results 72
3.7. Conclusion 83
3.8. Bibliography 83

Chapter 4. Metaheuristics for Trajectory Generation by Polynomial Interpolation 87

4.1. Introduction 87
4.2. Description of the problem addressed 88
4.3. Formalization 91
4.3.1. Criteria 91
4.3.2. Constraints 92
4.4. Resolution 94
4.4.1. Augmented Lagrangian 95
4.4.2. Genetic operators 97
4.4.3. Solution coding 99
4.5. Simulation results 100
4.6. Conclusion 116
4.7. Bibliography 118

Chapter 5. Particle Swarm Optimization for Exoskeleton Control 121

5.1. Introduction 121
5.2. The system and the problem under consideration . . . 123
5.2.1. Representation and model of the system under consideration 123
5.2.2. The problem under consideration 125
5.3. Proposed control algorithm 126
5.3.1. The standard PSO algorithm 126
5.3.2. Proposed control approach 128
5.4. Experimental results 135
5.5. Conclusion 142
5.6. Bibliography 143

Conclusion 147

Index 153