

Contents

List of figures	xi
List of tables	xvii
Biography	xix
Preface	xxi
1. Introduction	
1.1 Soft robots: An overview	1
1.2 Soft actuators	2
1.2.1 Shape memory materials	2
1.2.2 Pneumatic actuators	3
1.2.3 Electroactive polymers	5
1.2.4 Dielectric elastomer actuators	5
1.2.5 Other soft actuators	7
1.3 Key challenges	9
1.4 Motion control	10
1.4.1 Feedforward control	10
1.4.2 Feedback control	11
1.4.3 Feedforward plus feedback control	11
1.5 Organization of the book	12
References	13
2. Motion control of soft actuators and robots	
2.1 Introduction	17
2.2 Modeling	19
2.2.1 Analytical models	19
2.2.2 Numerical models	22
2.2.3 Data-driven models	22
2.3 Model-based control	23
2.4 Model-free control	25
2.5 Bioinspired control	26
2.6 Chapter summary	30
References	31
3. Robust motion control of a soft inchworm robot	
3.1 Introduction	37
3.2 System description	39
3.2.1 Robot design	39
3.2.2 Robot motion kinematics analysis	40

3.2.3	Robot dynamic modeling	42
3.3	Controller design	44
3.3.1	Model-based feedforward controller	46
3.3.2	PID-based feedback controller	46
3.3.3	DOB-based compensation	47
3.3.4	Overall controller	47
3.4	Experiments and results	48
3.4.1	Experimental system setup	48
3.4.2	Experimental results	49
3.5	Chapter summary	54
	References	55

4. Motion control of a circular soft robot via iterative learning control

4.1	Introduction	59
4.2	System description	61
4.2.1	Robot design	61
4.2.2	Locomotion analysis	64
4.2.3	Knowledge-based modeling	64
4.3	Controller design	70
4.3.1	ILC design	70
4.4	Numerical study	72
4.4.1	Simulation results on a simple trajectory	72
4.4.2	Simulation results on target motion trajectory	73
4.5	Experiments and results	76
4.5.1	Experimental system setup	76
4.5.2	Experimental results	76
4.6	Chapter summary	77
	References	78

5. Motion control of a muscle-like soft actuator

5.1	Introduction	81
5.2	System description	83
5.2.1	Design and fabrication of the soft actuator	83
5.2.2	Self-sensing of the muscle-like actuator	84
5.2.3	System modeling	86
5.3	Controller design	90
5.3.1	Bioinspired control system of the DEA	90
5.3.2	Cerebellum-inspired controller of the muscle-like actuator	92
5.4	Experiments and results	97
5.4.1	Experimental system setup	97
5.4.2	Experimental results	98
5.5	Conclusions	101
	References	101

6.	Bioinspired motion control of an antagonistic dielectric elastomer actuator-driven manipulator	
6.1	Introduction	105
6.2	System description	106
6.2.1	Mechanical design	106
6.2.2	Kinetics analysis	112
6.3	Controller design	114
6.3.1	Cerebellar model articulation controller	115
6.3.2	Compensation controller	118
6.3.3	Overall controller	119
6.3.4	Stability analysis	119
6.4	Experiments and results	121
6.4.1	Prototype and experimental system setup	121
6.4.2	Experimental results	122
6.5	Chapter summary	129
	References	129
7.	Bioinspired motion control of antagonistic McKibben muscles	
7.1	Introduction	133
7.2	System description	135
7.2.1	Mechanical design of antagonistic McKibben muscles	135
7.2.2	Kinematics analysis	136
7.2.3	System dynamic modeling	137
7.3	Controller design	138
7.3.1	Cerebellar control loop	139
7.3.2	Cerebellar network model	141
7.3.3	Cerebellar learning mechanism	144
7.4	Experiments	145
7.4.1	Experimental system setup	146
7.4.2	Experimental results	148
7.5	Chapter summary	154
	References	155
8.	Bioinspired learning-based motion control of a soft mobile robot	
8.1	Introduction	159
8.2	System description	161
8.2.1	Robot design	162
8.2.2	Locomotion analysis	163
8.3	Controller design	165
8.3.1	Actuator motion control	166
8.3.2	Reinforcement learning-based robot motion selection	171
8.3.3	Overall motion selection and control framework	175
8.4	Numerical study	175
8.4.1	Actuator motion control	175

x Contents

8.4.2	Motion selection	176
8.4.3	Movement task test	178
8.5	Experiments and results	179
8.5.1	Experimental system setup	179
8.5.2	Experimental results	179
8.6	Chapter summary	180
	References	182

9. Conclusions

Index	187
-------	-----