

Contents

1	Introduction: Exoskeletons in Rehabilitation Robotics ...	1
1.1	Introduction to Rehabilitation Robotics: Tremor Management	1
1.2	Historical Note on Rehabilitation Robotics	5
1.3	The Role of Robotic Exoskeletons in Rehabilitation	7
1.4	Salient Issues in Exoskeletal Rehabilitation Robotics	10
1.4.1	Bioinspiration	12
1.4.2	Mechanisms and Dynamic Models	13
1.4.3	Physical HRI in the Context of Exoskeletal Robots	13
1.4.4	Cognitive HMI in the Context of Exoskeletal Robots	14
1.4.5	Sensors, Actuators and Supporting Technologies	16
1.5	Scope of the Book	16
2	Pathological Tremor Management	21
2.1	Introduction	21
2.2	Tremor Manifestations	22
2.3	Tremor Patterns	24
2.3.1	Essential Tremor	26
2.3.2	Parkinsonian tremor	27
2.3.3	Cerebellar tremor	28
2.4	Tremor Characterization at Joint Level	29
2.4.1	Measuring Tremor: The Experimental Protocol	31
2.4.2	Studying Tremor: The Hilbert Spectrum	35
2.4.3	Tremor Study Based on Empirical Mode Decomposition	45
2.4.4	Study of Tremor Characteristics Based on a Biomechanical Model of the Upper Limb	46
2.5	Conclusions	50

3	Upper Limb Exoskeleton for Tremor Suppression:	
	Cognitive HR Interaction	53
3.1	Tremor Isolation	54
3.2	Estimation of Voluntary Movement	55
3.2.1	Two Points Extrapolator	57
3.2.2	g-h Filters	57
3.2.3	The Kalman Filter	61
3.2.4	Figure of Merit	63
3.3	Real-Time Estimation of Voluntary and Tremorous Movement	64
3.4	Conclusions	65
4	Upper Limb Exoskeleton for Tremor Suppression:	
	Physical HR Interaction	67
4.1	Biomechanics of the Upper Limb	68
4.1.1	Tolerance to Pressure	68
4.1.2	Mechanical Characterization of Soft Tissues at the Upper-Limb	69
4.2	Wearable Orthosis for Tremor Assessment and Suppression, WOTAS	71
4.2.1	Mechanical Design	71
4.2.2	Sensors	74
4.2.3	Actuators	75
4.3	Control Architecture	77
4.4	Control Strategies for Tremor Suppression	78
4.4.1	Tremor Reduction through Impedance Control	80
4.4.2	Exploitation of the Repetitive Characteristics of Tremor Movement	90
4.5	Conclusions	97
5	Upper Limb Exoskeleton for Tremor Suppression:	
	Validation	99
5.1	Experimental Protocol	99
5.1.1	Users	99
5.1.2	Materials and Methods	100
5.1.3	Tasks	101
5.1.4	Data Analysis	102
5.2	Results and Discussion	102
5.3	Discussion	108
5.4	Conclusions	110

- 6 Summary, Conclusions and Upcoming Research 113**
 - 6.1 Summary 113
 - 6.2 Conclusions 116
 - 6.3 Upcoming Research 117
 - 6.3.1 Development of Algorithms to Identify Intention to Move 125
 - 6.3.2 Development of Algorithms to Identify Tremor Onset 125
 - 6.3.3 Development of Algorithms for Tracking and Extraction of Tremor Characteristics 127
- References 131