Introduction to Autonomous Mobile Robots

Roland Siegwart and Illah R. Nourbakhsh

A Bradford Book The MIT Press Cambridge, Massachusetts London, England

Contents

Acı	Acknowledgments			
Preface				
1	Intr	Introduction		
	1.1	Introduction	1	
	1.2	An Overview of the Book	10	
2	Locomotion		13	
	2.1	Introduction	13	
		2.1.1 Key issues for locomotion	16	
	2.2	Legged Mobile Robots	17	
		2.2.1 Leg configurations and stability	18	
		2.2.2 Examples of legged robot locomotion	21	
	2.3	Wheeled Mobile Robots	30	
		2.3.1 Wheeled locomotion: the design space	31	
		2.3.2 Wheeled locomotion: case studies	38	
3	Mobile Robot Kinematics		47	
	3.1	Introduction	47	
	3.2	Kinematic Models and Constraints	48	
		3.2.1 Representing robot position	48	
		3.2.2 Forward kinematic models	51	
		3.2.3 Wheel kinematic constraints	53	
		3.2.4 Robot kinematic constraints	61	
		3.2.5 Examples: robot kinematic models and constraints	63	
	3.3	Mobile Robot Maneuverability	67	
		3.3.1 Degree of mobility	67	
		3.3.2 Degree of steerability	71	
		3.3.3 Robot maneuverability	72	

viii Contents

	3.4	Mobile Robot Workspace	74
		3.4.1 Degrees of freedom	74
		3.4.2 Holonomic robots	75
		3.4.3 Path and trajectory considerations	77
	3.5	Beyond Basic Kinematics	80
	3.6	Motion Control (Kinematic Control)	81
		3.6.1 Open loop control (trajectory-following)	81
		3.6.2 Feedback control	82
4	Pero	ception	89
	4.1	Sensors for Mobile Robots	89
		4.1.1 Sensor classification	89
		4.1.2 Characterizing sensor performance	92
		4.1.3 Wheel/motor sensors	97
		4.1.4 Heading sensors	98
		4.1.5 Ground-based beacons	101
		4.1.6 Active ranging	104
		4.1.7 Motion/speed sensors	115
		4.1.8 Vision-based sensors	117
	4.2	Representing Uncertainty	145
		4.2.1 Statistical representation	145
		4.2.2 Error propagation: combining uncertain measurements	149
	4.3	Feature Extraction	151
		4.3.1 Feature extraction based on range data (laser, ultrasonic, vision-l	based
		ranging)	154
		4.3.2 Visual appearance based feature extraction	163
5	Mol	oile Robot Localization	181
	5.1	Introduction	181
	5.2	The Challenge of Localization: Noise and Aliasing	182
		5.2.1 Sensor noise	183
		5.2.2 Sensor aliasing	184
		5.2.3 Effector noise	185
		5.2.4 An error model for odometric position estimation	186
	5.3	To Localize or Not to Localize: Localization-Based Navigation versus	
		Programmed Solutions	191
	5.4	Belief Representation	194
		5.4.1 Single-hypothesis belief	194
		5.4.2 Multiple-hypothesis belief	196

Contents ix

	5.5	Map Representation	200
		5.5.1 Continuous representations	200
		5.5.2 Decomposition strategies	203
		5.5.3 State of the art: current challenges in map representation	210
	5.6	Probabilistic Map-Based Localization	212
		5.6.1 Introduction	212
		5.6.2 Markov localization	214
		5.6.3 Kalman filter localization	227
	5.7	Other Examples of Localization Systems	244
		5.7.1 Landmark-based navigation	245
		5.7.2 Globally unique localization	246
		5.7.3 Positioning beacon systems	248
		5.7.4 Route-based localization	249
	5.8	Autonomous Map Building	250
		5.8.1 The stochastic map technique	250
		5.8.2 Other mapping techniques	253
6	Planning and Navigation		
	6.1	Introduction	257
	6.2	Competences for Navigation: Planning and Reacting	258
		6.2.1 Path planning	259
		6.2.2 Obstacle avoidance	272
	6.3	Navigation Architectures	291
		6.3.1 Modularity for code reuse and sharing	291
		6.3.2 Control localization	291
		6.3.3 Techniques for decomposition	292
		6.3.4 Case studies: tiered robot architectures	298
Rih	liograj	nhv	305
DIU	Boo		305
	Pape		306
	-	prenced Webpages	314
		resting Internet Links to Mobile Robots	314
Ind	ev		317