

Contents

1 Introduction	1
Anibal Ollero	
1.1 The State of the Art and Future of Aerial Robotics	1
1.1.1 Physical Interactions	2
1.1.2 Aerial Manipulation	5
1.1.3 The Design of Aerial Manipulation Systems	8
1.1.4 Applications	11
1.1.5 Conclusions and Future of Aerial Robotics	12
1.2 Structure of the Book	13
References	16
2 Coordinate Systems and Transformations	19
2.1 Coordinate Systems	19
2.1.1 Global Coordinate System	19
2.1.2 Local Coordinate System	21
2.1.3 Coordinate System Representation	22
2.2 Coordinate Transformations	23
2.2.1 Orientation Representation	24
2.2.2 Euler Angles	25
2.2.3 Change of Frame	26
2.2.4 Translation and Rotation	26
2.3 Motion Kinematics	28
2.3.1 Linear and Angular Velocities	28
2.3.2 Rotational Transformations of a Moving Body	29
References	31
3 Multirotor Aerodynamics and Actuation	33
3.1 The Aerodynamics of Rotary Flight	33
3.1.1 Momentum Theory	34

3.1.2	Blade Element Theory	39
3.2	Different Multirotor Configurations	44
3.2.1	Coplanar Configuration of Propulsors	45
3.2.2	Independent Control of All 6 DOF	48
3.3	Aerial Manipulation Actuation	51
3.3.1	DC Motor	52
3.3.2	Brushless DC Motor	67
3.3.3	Servo Drives	72
3.3.4	2-Stroke Internal Combustion Engine	75
	References	85
4	Aerial Manipulator Kinematics	87
4.1	Manipulator Concept	87
4.2	Forward Kinematics	88
4.2.1	DH Kinematic Parameters	89
4.2.2	The Arm Equation	93
4.2.3	Moving Base Frame	97
4.3	Inverse Kinematics	100
4.3.1	Tool Configuration	100
4.3.2	Existence and Uniqueness of Solution	101
4.3.3	Closed-Form Solutions	103
4.3.4	Iterative Methods	105
4.4	Inverse Kinematics Through Differential Motion	110
4.4.1	Jacobian Matrix	111
4.4.2	Inverse Kinematics—Jacobian Method	113
4.4.3	Inverting the Jacobian	115
	References	122
5	Aerial Manipulator Dynamics	123
5.1	Newton–Euler Dynamic Model	123
5.1.1	Forward Equations in Fixed Base Coordinate System	123
5.1.2	Forward Equations in a UAV (Moving) Coordinate System	127
5.1.3	Multiple Rigid Body System Mass and Moment of Inertia	128
5.1.4	Backward Equations	131
5.2	Lagrange–Euler Model	143
5.2.1	Aerial Robot Kinetic Energy	146
5.2.2	Moment of Inertia	147

- 5.3 Dynamics of Aerial Manipulator in Contact with Environment 153
 - 5.3.1 Momentary Coupling 156
 - 5.3.2 Loose Coupling. 157
 - 5.3.3 Strong Coupling 159
- References. 162
- 6 Sensors and Control 165**
 - 6.1 Sensors 165
 - 6.1.1 Inertial Measurement Unit. 165
 - 6.1.2 Cameras 166
 - 6.1.3 GPS 167
 - 6.1.4 Motion Capture. 167
 - 6.2 Sensor Fusion 168
 - 6.2.1 Attitude Estimation 169
 - 6.2.2 Position Estimation 170
 - 6.3 Linear Control System 173
 - 6.3.1 Attitude Control 175
 - 6.3.2 Position Control 181
 - 6.4 Robust and Adaptive Control Applications. 184
 - 6.4.1 Gain Scheduling 184
 - 6.4.2 Model Reference Adaptive Control. 186
 - 6.4.3 Backstepping Control 190
 - 6.4.4 Hsia - a Robust Adaptive Control Approach. 198
 - 6.5 Impedance Control 200
 - 6.6 Switching Stability of Coupling Dynamics. 203
 - References. 206
- 7 Mission Planning and Control 209**
 - 7.1 Path Planning 211
 - 7.1.1 Trajectory Generation 212
 - 7.2 Obstacle-Free Trajectory Planning 217
 - 7.2.1 Local Planner 217
 - 7.2.2 Global Planner 218
 - 7.3 Vision-Guided Aerial Manipulation 221
 - 7.3.1 Autonomous Pick and Place 221
 - 7.3.2 Transforming Camera-Detected Pose to Global Pose 224
 - References. 229
- Erratum to: Introduction E1**
- Index 233**



<http://www.springer.com/978-3-319-61020-7>

Aerial Manipulation

Orsag, M.; Korpela, C.; Oh, P.; Bogdan, S.

2018, XV, 235 p. 148 illus., 98 illus. in color. With online files/update., Hardcover

ISBN: 978-3-319-61020-7