

Contents

Acknowledgments	xi
List of Acronyms	xiii
Preface	xv
Fabio MORBIDI and Pascal VASSEUR	
Chapter 1. Image Geometry	1
Peter STURM	
1.1. Introduction	2
1.1.1. Outline of this chapter	5
1.2. Image formation and point-wise approximation	6
1.3. Projection and back-projection	7
1.4. Central and non-central cameras	12
1.5. “Outer” geometry: calibrated cameras	16
1.5.1. Given an image of a scene and a particular point in that image, where could the original point in the scene possibly be located?	17
1.5.2. Is it possible to precisely locate an object in 3D from a single image and if yes, what information is required to do so and how do we solve this problem mathematically?	17
1.5.3. Is it possible to estimate the motion of a camera just by taking images of an unknown scene?	19
1.5.4. Triangulation – reconstructing 3D points	21
1.5.5. Some remarks	22

1.6. “Inner” geometry: images of lines	24
1.7. Epipolar geometry	26
1.7.1. Nature of epipolar geometry	26
1.7.2. Dense stereo matching and rectification	31
1.8. Conclusion	35
1.9. Acknowledgments	35
1.10. References	36
Chapter 2. Models and Calibration Methods	39
Guillaume CARON	
2.1. Introduction	39
2.2. Projection models	40
2.2.1. Perspective projection: a review	40
2.2.2. Ad hoc models	43
2.2.3. Unified central projection and its extensions	49
2.2.4. Generic models	54
2.3. Calibration methods	54
2.4. Conclusion	57
2.5. References	59
Chapter 3. Reconstruction of Environments	63
Maxime LHUILLIER	
3.1. Prerequisites	64
3.1.1. Image rectification and matching constraints	64
3.1.2. From disparity to depth	65
3.1.3. Dynamic programming and semi-global matching methods (SGM)	66
3.1.4. Plane sweeping methods	67
3.1.5. Minimization of global energy (or cost function)	67
3.1.6. Propagation methods	68
3.1.7. Surface reconstruction methods	70
3.1.8. Estimation of the 3D using other sensors	72
3.2. Pros and cons for using omnidirectional cameras	72
3.2.1. Multi-cameras	73
3.2.2. Catadioptric cameras	73
3.2.3. Toward a wide use of the 360° cameras	75

3.3. Adapt dense stereo to omnidirectional cameras	75
3.3.1. Spherical rectifications	76
3.3.2. Cylindrical rectifications	79
3.3.3. Planar rectifications	80
3.3.4. Sphere sweeping	81
3.3.5. Neither sweeping nor standard rectification	83
3.4. Reconstruction from only one central image	84
3.4.1. Explicit use of geometric constraints	85
3.4.2. Deep learning	86
3.5. Reconstruction using stationary non-central camera	87
3.6. Reconstruction by a moving camera	89
3.6.1. From local to global models	89
3.6.2. Sparse approaches for local models	92
3.6.3. Sparse approaches for global models	93
3.6.4. Available software	98
3.7. Conclusion	99
3.8. References	100
Chapter 4. Catadioptric Processing and Adaptations	105
Fatima AZIZ, Ouiddad LABBANI-IGBIDA and Cédric DEMONCEAUX	
4.1. Introduction	105
4.2. Preliminary concepts	106
4.2.1. Spherical equivalence models	106
4.2.2. Differential calculus and Riemannian geometry	108
4.3. Adapted image processing by differential calculus on quadratic surfaces	110
4.3.1. Riemannian geometry for hyperbolic mirrors	111
4.3.2. Riemannian geometry for spherical mirrors	111
4.3.3. Riemannian geometry for paraboloid mirrors	113
4.3.4. Application to active contour deformation	114
4.4. Adapted image processing by Riemannian geodesic metrics	115
4.4.1. Spatial Riemannian metric	117
4.4.2. Spatial-color metric	118
4.4.3. Application to Gaussian kernel based smoothing	119
4.4.4. Application to corner features detection	120
4.5. Adapted image processing by spherical geodesic distance	121
4.5.1. Neighborhood definition	123
4.5.2. Application to linear catadioptric image filtering	125

4.5.3. Application to corner features detection and matching	127
4.6. Conclusion	132
4.7. References	133
Chapter 5. Non-Central Sensors and Robot Vision	135
Sio-hoi IENG	
5.1. Introduction	135
5.1.1. Generalities	137
5.1.2. Biological eyes	138
5.2. Catadioptric sensors: reflector computation	139
5.2.1. Caustic surface of a catadioptric system	140
5.2.2. Caustic surface computation	141
5.2.3. Reflector computation	144
5.2.4. Methods for reflector with no axial symmetry	146
5.3. Plenoptic vision as a unique form of non-central vision	149
5.3.1. Formalism and design	150
5.3.2. Plenoptic camera	151
5.3.3. Applications in robotic navigation: plenoptic visual odometry	152
5.4. Conclusion	155
5.5. References	157
Chapter 6. Localization and Navigation with Omnidirectional Images	159
Helder Jesus ARAÚJO, Pedro MIRALDO and Nathan CROMBEZ	
6.1. Introduction	160
6.2. Modeling image formation of omnidirectional cameras	163
6.2.1. Central systems	165
6.2.2. Non-central systems	169
6.2.3. Mirrors with special profiles	171
6.2.4. Fisheye lenses	175
6.3. Localization and navigation	177
6.3.1. Metric localization and mapping	178
6.3.2. Topological localization and mapping	184
6.3.3. Visual odometry	189
6.3.4. SLAM	197
6.3.5. Multi-robot formation	206

6.4. Conclusion	209
6.5. References	210
Conclusion and Perspectives	219
Fabio MORBIDI and Pascal VASSEUR	
List of Authors	223
Index	225