

Contents

1	Introduction	1
1.1	Tasks for Photogrammetric Computer Vision	2
1.2	Modelling in Photogrammetric Computer Vision	6
1.3	The Book	11
1.4	On Notation	16
 Part I Statistics and Estimation		
2	Probability Theory and Random Variables	21
2.1	Notions of Probability	21
2.2	Axiomatic Definition of Probability	22
2.3	Random Variables	24
2.4	Distributions	28
2.5	Moments	36
2.6	Quantiles of a Distribution	40
2.7	Functions of Random Variables	40
2.8	Stochastic Processes	48
2.9	Generating Random Numbers	55
2.10	Exercises	56
3	Testing	61
3.1	Principles of Hypothesis Testing	61
3.2	Testability of an Alternative Hypothesis	65
3.3	Common Tests	69
3.4	Exercises	72
4	Estimation	75
4.1	Estimation Theory	75
4.2	The Linear Gauss–Markov Model	81
4.3	Gauss–Markov Model with Constraints	99
4.4	The Nonlinear Gauss–Markov Model	102
4.5	Datum or Gauge Definitions and Transformations	108
4.6	Evaluation	115
4.7	Robust Estimation and Outlier Detection	141
4.8	Estimation with Implicit Functional Models	160
4.9	Methods for Closed Form Estimations	176
4.10	Estimation in Autoregressive Models	183
4.11	Exercises	185

Part II Geometry

5	Homogeneous Representations of Points, Lines and Planes	195
5.1	Homogeneous Vectors and Matrices	195
5.2	Homogeneous Representations of Points and Lines in 2D	205
5.3	Homogeneous Representations in \mathbb{IP}^n	209
5.4	Homogeneous Representations of 3D Lines	216
5.5	On Plücker Coordinates for Points, Lines and Planes	221
5.6	The Principle of Duality	229
5.7	Conics and Quadrics	236
5.8	Normalizations of Homogeneous Vectors	241
5.9	Canonical Elements of Coordinate Systems	242
5.10	Exercises	245
6	Transformations	247
6.1	Structure of Projective Collineations	248
6.2	Basic Transformations	250
6.3	Concatenation and Inversion of Transformations	261
6.4	Invariants of Projective Mappings	266
6.5	Perspective Collineations	277
6.6	Projective Correlations	282
6.7	Hierarchy of Projective Transformations and Their Characteristics	284
6.8	Normalizations of Transformations	285
6.9	Conditioning	286
6.10	Exercises	287
7	Geometric Operations	291
7.1	Geometric Operations in 2D Space	292
7.2	Geometric Operations in 3D Space	299
7.3	Vector and Matrix Representations for Geometric Entities	311
7.4	Minimal Solutions for Conics and Transformations	316
7.5	Exercises	322
8	Rotations	325
8.1	Rotations in 3D	325
8.2	Concatenation of Rotations	337
8.3	Relations Between the Representations for Rotations	338
8.4	Rotations from Corresponding Vector Pairs	339
8.5	Exercises	340
9	Oriented Projective Geometry	343
9.1	Oriented Entities and Constructions	344
9.2	Transformation of Oriented Entities	355
9.3	Exercises	358
10	Reasoning with Uncertain Geometric Entities	359
10.1	Motivation	360
10.2	Representing Uncertain Geometric Elements	364
10.3	Propagation of the Uncertainty of Homogeneous Entities	386
10.4	Evaluating Statistically Uncertain Relations	393
10.5	Closed Form Solutions for Estimating Geometric Entities	395
10.6	Iterative Solutions for Maximum Likelihood Estimation	414
10.7	Exercises	432

Part III Orientation and Reconstruction

11 Overview	441
11.1 Scene, Camera, and Image Models	441
11.2 The Setup of Orientation, Calibration, and Reconstruction	449
11.3 Exercises	453
12 Geometry and Orientation of the Single Image	455
12.1 Geometry of the Single Image	456
12.2 Orientation of the Single Image	489
12.3 Inverse Perspective and 3D Information from a Single Image	523
12.4 Exercises	537
13 Geometry and Orientation of the Image Pair	547
13.1 Motivation	547
13.2 The Geometry of the Image Pair	549
13.3 Relative Orientation of the Image Pair	568
13.4 Triangulation	596
13.5 Absolute Orientation and Spatial Similarity Transformation	607
13.6 Orientation of the Image Pair and Its Quality	608
13.7 Exercises	615
14 Geometry and Orientation of the Image Triplet	621
14.1 Geometry of the Image Triplet	622
14.2 Relative Orientation of the Image Triplet	632
14.3 Exercises	641
15 Bundle Adjustment	643
15.1 Motivation for Bundle Adjustment and Its Tasks	644
15.2 Block Adjustment	645
15.3 Sparsity of Matrices, Free Adjustment and Theoretical Precision	651
15.4 Self-calibrating Bundle Adjustment	674
15.5 Camera Calibration	696
15.6 Outlier Detection and Approximate Values	707
15.7 View Planning	715
15.8 Exercises	722
16 Surface Reconstruction	727
16.1 Introduction	727
16.2 Parametric $2^{1/2}$ D Surfaces	733
16.3 Models for Reconstructing One-Dimensional Surface Profiles	742
16.4 Reconstruction of $2^{1/2}$ D Surfaces from 3D Point Clouds	757
16.5 Examples for Surface Reconstruction	763
16.6 Exercises	765
Appendix: Basics and Useful Relations from Linear Algebra	767
A.1 Inner Product	767
A.2 Determinant	767
A.3 Inverse, Adjugate, and Cofactor Matrix	769
A.4 Skew Symmetric Matrices	770
A.5 Eigenvalues	772
A.6 Idempotent Matrices	774
A.7 Kronecker Product, $\text{vec}(\cdot)$ Operator, $\text{vech}(\cdot)$ Operator	775

A.8 Hadamard Product	776
A.9 Cholesky and QR Decomposition	776
A.10 Singular Value Decomposition	777
A.11 The Null Space and the Column Space of a Matrix	777
A.12 The Pseudo-inverse	779
A.13 Matrix Exponential	781
A.14 Tensor Notation	782
A.15 Variance Propagation of Spectrally Normalized Matrix	783
References	785
Index	799

Photogrammetric Computer Vision

Statistics, Geometry, Orientation and Reconstruction

Förstner, W.; Wrobel, B.P.

2016, XVII, 816 p. 281 illus., 59 illus. in color.,

Hardcover

ISBN: 978-3-319-11549-8