

Contents

<u>Introduction</u>	
E.W. GRAFAREND	1
<u>A Review of Network Designs: Criteria, Risk Functions, Design Ordering</u>	
G. SCHMITT	6
1. Classification	6
2. Objective Functions	7
3. Solution Methods	9
References	10
 <u>B. Zero Order Design:</u>	
<u>Generalized Inverses, Adjustment, the Datum Problem</u>	
<u>and S-Transformations (With 15 Figures)</u>	
P. TEUNISSEN	11
0.1 Introduction	11
0.2 Notations and Preliminaries	12
1. Generalized Inverses, a Geometric Approach	14
1.1 Characterization of a Set of Linear Equations	14
1.2 A Unique Characterization of an Arbitrary	
Generalized Inverse	17
1.3 Right - and Left Inverses	21
1.4 An Arbitrary System of Linear Equations and	
Arbitrary Generalized Inverses	25
1.5 Transformation Properties and Some Special	
Types of Generalized Inverses	27
1.6 Summary	30
2. On S-Transformations	32
2.1 Introduction	32
2.2 Coordinates and Datum Definitions	33
2.3 S-Transformations	40
2.4 The Relation with Generalized Inverses	53
References	54
 <u>C. First Order Design:</u>	
<u>Optimization of the Configuration of a Network by Introducing</u>	
<u>Small Position Changes</u>	
K.R. KOCH	56
1. Introduction	56
2. Gauß-Markof Models Not of Full Rank	56

3. Projected Parameters	57
4. Datum Transformations	58
5. Choice of the Datum for a Free Network	61
6. Choice of a Criterion Matrix for a Free Network	64
7. First Order Design Problem by Introducing Small Position Changes	65
8. Criterion Matrix for the Optimization	66
9. Optimization Problem	67
10. Quadratic Programming Problem	68
11. Linear Complementary Problem	70
12. Solution of the Linear Complementary Problem	71
References	73
 <u>D. Second Order Design (With 12 Figures)</u>	
G. SCHMITT	74
0. An Example	74
1. Three SOD-Approaches	78
1.1 Direct Approximation of the Criterion Matrix, Approach i)	78
1.2 Iterative Approximation of the Criterion Matrix, Approach ii)	79
1.3 Direct Approximation of the Inverse Criterion Matrix, Approach iii)	80
1.4 Diagonal Design	80
1.5 Approximation Quality	81
1.6 Modification of Approach iii)	82
2. Solution Methods	83
2.1 Least-Squares Solution	83
2.2 Linear Programming	83
2.3 Nonlinear Programming	84
3. Mean Least-Squares Approximation, Comparison of the Three Approaches	87
4. Directions in the SOD-Problem	89
4.1 Elimination and Group Weights	90
4.2 Elimination and Individual Weights	90
4.3 Correlated Angles	91
4.4 Extracted Khatri-Rao-Product and Individual Weights	92
4.5 Comparison	92
4.6 Three-Step-Strategy	93
5. Defect Analysis of the Final Equation	94
5.1 Defect Analysis for Distances	94
5.2 Free Distance Networks	96
5.3 Defect Analysis for Directions	97
5.4 Free Direction Networks	99
6. Direct Creation of the Final Equation	102
6.1 Individual Weights	103
6.1.1 Distances	103
6.1.2 Directions	105
6.1.3 Mixed Network	106
6.2 Group Weights	107
6.3 Common Weights for Sets of Directions	108
7. Examples	112
7.1 Example 1	112
7.2 Example 2	113
References	120

<u>E. Third Order Design</u>	
G. SCHMITT	122
1. THOD as Instrument in FOD and SOD	122
2. Mathematical Model for Network Densification	124
3. THOD with Criterion Matrices	128
References	131
 <u>F. Numerical Methods in Network Design (With 1 Figure)</u>	
P.A. CROSS	132
1. Introduction	132
2. Optimal Design Problems	132
2.1 Precision Criteria	133
3. Network Design Strategies	134
3.1 Computer Simulation	135
3.2 Analytical Methods	138
3.2.1 Generalized Matrix Algebra	139
3.2.2 Linear Programming	140
3.2.3 Non-Linear Programming	145
4. Conclusions	146
Appendix A: Linear Programming	147
Appendix B: Generalized Matrix Algebra	153
Appendix C: Least Squares Techniques	158
References	164
 <u>G. Some Additional Information on the Capacity of the Linear Complementarity Algorithm (With 3 Figures)</u>	
D. FRITSCH	169
1. Introduction	169
2. Inequality Constrained Least-Squares Approximation	172
3. The Linear Complementarity Algorithm	176
4. Examples	180
References	183
 <u>H. Quick Computation of Geodetic Networks Using Special Properties of the Eigenvalues (With 15 Figures)</u>	
W.D. SCHUH	185
1. Introduction	185
2. Iterative Procedures	186
3. Properties of the Conjugate Gradient Method	187
4. Acceleration of the Convergence by an Approximation with Finite Elements	190
5. Survey of Formulae	193
5.1 Conjugate Gradient Method	193
5.2 Approximation with Finite Elements	194
References	195
 <u>I. Estimability Analyses of the Free Networks of Differential Range Observations to GPS Satellites (With 2 Figures)</u>	
D. DELIKARAOGLOU	196
1. Introduction	196
2. Types of Rank Deficiencies	197

3. Rank Deficiencies of Free Networks Based on Differential Range GPS Observations	199
3.1 Determination of Station and Satellite Coordinates	199
3.2 Determinations of Station, Satellite and Non-Geometric Parameters	202
4. Estimability Analysis	206
4.1 Patterns of Observations for Moving Stations	206
4.2 General Criteria of Estimability for Subnetwork Design	207
5. Numerical Adjustment	209
6. A-Priori Information in GPS Satellite Networks	210
7. Effect of A-Priori Constraints on the Adjustment Results.....	214
8. Summary and Conclusions.....	218
References	219

<u>J. Optimization Problems in Geodetic Networks with Signals</u>	
A. DERMANIS	221
1. Introduction	221
2. Data Analysis and Signals	223
3. Geodetic Networks with Signals.....	225
4. Different Approaches for the Adjustment of Observations Depending on Signals	226
4.1 The Deterministic Approach	227
4.2 The Model Function Approach	228
4.3 The Stochastic Approach	229
4.4 Hybrid Approaches	230
5. Zero Order Design with Signals	232
5.1 General Remarks	232
5.2 Three-dimensional Networks	234
6. Deformable Networks	240
7. Estimability Problems	244
8. Other Optimization Problems	247
8.1 General Remarks	247
8.2 First Order Design	248
8.3 Second Order Design	250
8.4 Third Order Design	251
Appendix: Observation Equations of Three-dimensional Networks	252
References	255

<u>K. Fourier Analysis of Geodetic Networks (With 13 Figures)</u>	
H. SÖNKEL.....	257
0. Introduction	257
1. Spectral Methods in Geodesy	258
1.1 Fourier Techniques in Interpolation Methods	261
1.1.1 Step Function "Interpolation".....	262
1.1.2 Piecewise Linear Interpolation.....	266
1.1.3 Quadratic Spline Interpolation.....	267
1.1.4 Cubic Spline Interpolation.....	272
1.1.5 Higher and Highest Order Spline Interpolation.....	277
1.2 Fourier Techniques in Physical Geodesy	284
2. Distributions and Fourier Transforms	289
3. Leveling Lines, Leveling Networks	292
4. Traverse, Trilateration Networks	296
References	299

<u>L. Continuous Networks I (With 6 Figures)</u>	
E.W. GRAFAREND and F. KRUMM	301
0. Introduction	301
1. Continuous Networks of First Derivative Type	302
1.1 Networks on a Line	303
1.1.1 The Fixed Network.....	303
1.1.2 The Free Network.....	309
1.2 Networks on a Circle	315
1.3 Variance - Covariance Function of Estimable Quantities	322
1.4 Higher Dimensional Networks	323
2. Continuous Networks of Second Derivative Type	324
3. Discrete versus Continuous Geodetic Networks	336
References	340
 <u>M. Continuous Networks II (With 9 Figures)</u>	
B. BENCIOLINI.....	342
0. Introduction	342
1. Elementary Examples: A Single Line Leveling.....	342
2. On the Conditions for a Continuous Approximation of Network with some exceptions	350
3. A Planar Circular Leveling Network	355
Appendix: A Numerical Comparison Between a Discrete Network and its Continuous Analogue	361
References	362
 <u>N. Criterion Matrices for Deforming Networks (With 29 Figures)</u>	
E.W. GRAFAREND.....	363
0. Introduction.....	363
1. Deformation Measures and Their Finite Element Approximation.....	365
2. The Datum Problems in Estimating Deformation Measures.....	387
3. Criterion Matrices for Deformation Measures.....	393
4. Datum Transformation of a Criterion Matrix and the Comparison of Real Versus Ideal Dispersion Matrices by Factor Analysis.....	405
4.1 Datum Transformation of a Criterion Matrix.....	405
4.2 Canonical Comparison of an Ideal Versus a Real Variance- Covariance Matrix	412
4.2.1 The Eigenvalue Problem for the Matrix A	412
4.2.2 The Eigenvalue Problem for the Matrix B	413
4.2.3 The Eigenvalue Problem of General Type	413
4.3 Observational Equations of a Deforming Network.....	415
References	426
 <u>0. A Criterion Matrix for Deforming Networks by Multifactorial Analysis Techniques (With 2 Figures)</u>	
F. CROSILLA.....	429
1. Optimal Versus Improved Design	429
2. Essential Eigenvector Analysis	429
3. Procrustean Transformation	432
References	435

P. The Analysis of Time Series with Applications to Geodetic Control Problems (With 22 Figures)

F. SANSO.....	436
0. Foreword.....	436
1. Notations and Preliminaries.....	437
1.1 The Object of our Analysis.....	437
1.2 Prerequisites on Stochastic Processes.....	439
1.3 Stationarity.....	443
1.4 The Estimation of the Autocovariance Function.....	446
1.5 The Estimation of the Spectral Density.....	452
2. The Hilbert Space Setting.....	459
2.1 Basic Definitions	459
2.2 Establishing the Spectral Representation of the Time Series.....	462
2.3 The World Decomposition Theorem.....	470
2.4 Causality and Analytical Properties of the Spectral Functions.....	473
2.5 The General "Linear" Prediction Problem	480
3. The Autoregressive - Moving Average Processes	487
3.1 Definition of ARMA (p,g) Models.....	487
3.2 The Covariances of ARMA Processes	489
3.3 The Spectral Densities of ARMA Processes.....	493
3.4 The Yule-Walker Estimates and Forecasts.....	495
3.5 Examples.....	503
3.6 The Maximum Likelihood and "Least Squares" Estimates.....	513
3.7 Model Testing.....	522
References.....	525

Q. Quality Control in Geodetic Networks (With 9 Figures)

P.J.G. TEUNISSEN.....	526
0. Introduction.....	526
1. Model Assumptions and Estimation	527
2. Hypothesis Testing.....	531
3. Reliability	539
4. Precision	543
References	546

R. Aspects of Network Design (With 1 Figure)

B. SCHAFFRIN.....	548
0. Introduction	548
1. The Datum Problem for Criterion Matrices.....	549
2. The Fundamental Design Problems.....	556
3. The Canonical Formulation of the Second Order Design Problem with Respect to an S-System	558
4. Review of Optimization Principles	560
5. The "Choice-of-Norm" Problem for Network Optimization	566
6. Transformation of the Quadratic Program into a Linear Complementarity Problem	570
7. The Optimal Design within Mixed Linear Models	574
8. The Second Order Design and Third Order Design Problem within the Mixed Model	577

9. The Second Order Design Problem within Mixed Models Admitting a Singular Covariance Matrix $\Sigma_{ee} = \sigma^2 p_e^+$	581
Appendix 1: Criterion Matrices Reflecting Homogeneity and Isotropy	585
Appendix 2: Computational Rules for Matrix Products	588
Appendix 3: A Review of Reliability	590
References	595
Subject Index	598