Theoria Combinationis Observationum Erroribus Minimis Obnoxiae

Pars Prior ◆ Pars Posterior ◆ Supplementum

By Carl Friedrich Gauss



Theory of the Combination of Observations Least Subject to Errors

Part One ◆ Part Two ◆ Supplement

Translated by G. W. Stewart *University of Maryland*



Society for Industrial and Applied Mathematics Philadelphia 1995

Contents

Translator's Introduction	ix
Pars Prior/Part One*	1
1. Random and regular errors in observations	3
2. Regular errors excluded; their treatment	5
3. General properties of random errors	5
4. The distribution of the error	7
5. The constant part or mean value of the error	7
6. The mean square error as a measure of uncertainty	9
7. Mean error, weight, and precision	11
8. Effect of removing the constant part	11
9. Interpercentile ranges and probable error; properties of the uni-	13
form, triangular, and normal distribution	
10. Inequalities relating the mean error and interpercentile ranges	15
11. The fourth moments of the uniform, triangular, and normal distributions	19
12. The distribution of a function of several errors	21
13. The mean value of a function of several errors	21
14. Some special cases	23
15. Convergence of the estimate of the mean error; the mean error of the estimate itself; the mean error of the estimate for the mean value	25
16. Combining errors with different weights	27
17. Overdetermined systems of equations; the problem of obtaining the unknowns as combinations of observations; the principle of least squares	31
18. The mean error of a function of quantities with errors	33
19. The regression model	37
20. The best combination for estimating the first unknown	39
21. The weight of the estimate; estimates of the remaining unknowns and their weights; justification of the principle of least squares	43
22. The case of a single unknown; the arithmetic mean	45
Pars Posterior/Part Two	49
23. Existence of the least squares estimates	51
24. Relation between combinations for different unknowns	53

^{*}The titles of the numbered articles are the translator's and are intended to help orient the reader. They do not appear in the numbered articles.

•	_ :
V1	Contents

25. A formula for the residual sum of squares	55
26. Another formula for the residual sum of squares	57
27. Four formulas for the residual sum of squares as a function of	57
the unknowns	
28. Errors in the least squares estimates as functions of the errors	59
in the observations; mean errors and correlations	
29. Linear functions of the unknowns	61
30. Least squares with a linear constraint	63
31. Review of Gaussian elimination	67
32. Abbreviated computation of the weights of the unknowns	69
33. Computational details	71
34. Abbreviated computation of the weight of a linear function of	7 5
the unknowns	
35. Updating the unknowns and their weights when a new observa-	77
tion is added to the system	
36. Updating the unknowns and their weights when the weight of	83
an observation changes	
37. A bad formula for estimating the errors in the observations from	83
the residual sum of squares	
38. The correct formula	87
39. The mean error of the residual sum of squares	89
40. Inequalities for the mean error of the residual sum of squares;	95
the case of the normal distribution	
Supplementum/Supplement	99
1. Problems having constraints on the observations; reduction to	101
an ordinary least squares problem	
2. Functions of the observations; their mean errors	103
3. Estimating a function of observations that are subject to	105
constraints	
4. Characterization of permissible estimates	107
5. The function that gives the most reliable estimate	109
6. The value of the most reliable estimate	111
7. Four formulas for the weight of the value of the estimate	113
8. The case of more than one function	115
9. The most reliable adjustments of the observations and their use	119
in estimation	
10. Least squares characterization of the most reliable adjustment	119
11. Difficulties in determining weights	121
12. A better method	123
13. Computational details	125

14. Existence of the estimates	127
15. Estimating the mean error in the observations	131
16. Estimating the mean error in the observations, continued	135
17. The mean error in the estimate	137
18. Incomplete adjustment of observations	137
19. Relation between complete and incomplete adjustments	139
20. A block iterative method for adjusting observations	141
21. The inverse of a symetric system is symmetric	143
22. Fundamentals of geodesy	147
23. De Krayenhof's triangulation	149
24. A triangulation from Hannover	159
25. Determining weights in the Hannover triangulation	167
Anzeigen/Notices	173
Part One	175
Part Two	187
Supplement	195
Afterword	205
Gauss's Schooldays	207
Legendre and the Priority Controversy	210
Beginnings: Mayer, Boscovich, and Laplace	211
Gauss and Laplace	214
The Theoria Motus	214
Laplace and the Central Limit Theorem	217
The Theoria Combinationis Observationum	220
The Precision of Observations	220
The Combination of Observations	223
The Inversion of Linear Systems	225
Gaussian Elimination and Numerical Linear Algebra	227
The Generalized Minimum Variance Theorem	232
References	237