THE COMBINATION OF OBSERVATIONS

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649173006

The combination of observations by David Brunt

Except for use in any review, the reproduction or utilisation of this work in whole or in part in any form by any electronic, mechanical or other means, now known or hereafter invented, including xerography, photocopying and recording, or in any information storage or retrieval system, is forbidden without the permission of the publisher, Trieste Publishing Pty Ltd, PO Box 1576 Collingwood, Victoria 3066 Australia.

All rights reserved.

Edited by Trieste Publishing Pty Ltd. Cover @ 2017

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, re-sold, hired out, or otherwise circulated without the publisher's prior consent in any form or binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser.

www.triestepublishing.com

DAVID BRUNT

THE COMBINATION OF OBSERVATIONS

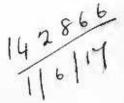
Trieste

THE COMBINATION OF OBSERVATIONS

BY

DAVID BRUNT, M.A. (Cantab.), B.Sc. (Wales)

Lecturer in Mathematics at the Monmouthshire Training College, Caerleon, Mon.



Cambridge: at the University Press 1917

PREFACE

unknown quantity will be found in the first four Chapters. Many of the problems of the physicist involve one unknown only, and the first four Chapters contain all the theory that has to be considered in the discussion of such problems. The subject of Chapter VII, the adjustment of conditioned observations, has only been outlined very briefly. The fuller development of the subject, which forms the basis of the adjustment of triangulations, will be found in the works to which reference is made at the end of Chapter VII. The last four Chapters can only be regarded as mere introductions to the subjects discussed, but it was thought that their inclusion in a textbook on Least Squares would be an advantage.

I have to acknowledge my indebtedness to Mr F. J. M. Stratton, of Gonville and Caius College, Cambridge, to whose University lectures I owe most of my knowledge of the subjects discussed in this book, and upon whose notes I have drawn freely. I have also to thank Professor Eddington for many useful suggestions made while the book was in manuscript form, and for permission to extract from his lecture notes a number of interesting examples as well as some portions of the theoretical treatment.

I cannot express adequately my debt to the Cambridge University Press, for the extreme care shown in passing the book through the proof stage. Owing to my being abroad at the time, I was not able to devote as much time as was desirable to the reading of proofs, and but for the unfailing vigilance of the Press, many errors would have been allowed to pass into the text.

DAVID BRUNT.

METEOROLOGICAI, SECTION, R.E. G. H. Q. November 23, 1916.

TABLE OF CONTENTS

CHAPTER I

ERRORS OF OBSERVATION

The nature of errors of observation	11	30	10	\mathbf{x}	100	×.			AGE 1
Frequency curves		-	962	×	-	*	30		6
Accuracy of the arithmetic mean		12	t:					5.	9

CHAPTER II

THE LAW OF ERROR

Hagen's proof	f of (Janss's	err	or lav	γ.	12	20		0.2	1	<u>a</u> .		11
Thomson and	Tai	t's pro	of	¥ .		S.	8 - R	12	80	яž.	1	1	14
Generalised f	orm	of Hag	en's	proo	f.	3	20	30	3	42	30	14	15
Form of the	error	eurvo		N	-		s #3	-	3			3	18
The arithmet				• 2	- 26				24				21
Derivation of	the n	ormall	aw	oferro	rs i	from	the pr	inciple	e of t	he ar	ithme	tic	
mean .					1						42		22
Law of error	of a	linear	fun	etion	of	two	indep	enden	t qui	antiti	es.		24
The median	12		a -	30	\mathbf{x}	- 14	1	(2)	1		S4.	16	27
Examples .	+:	-				13	10	30	63	87			28
References .							s 45						28

CHAPTER III

THE CASE OF ONE UNKNOWN

Measures of precision											29
Evaluation of h and r	(11)	÷.		22	3	a,	34	÷2	32		31
Comparison of a set of	obset	rvati	ons 1	sith	theory	÷.	1.1	**	36	14	33
Evaluation of μ .		*:						+:	240		33
Probable error and mea	in squ	are	erro	r of	the ari	thn	netic i	mean			36
Probable error of a line	ear fu	netio	on .		•		1		2		36
Probable error of the a	rithm	etic	moal	п.	2.0	4	2	1			37
Peters' formula for r					*		24.5	92	<u>s</u>		38

PREFACE

unknown quantity will be found in the first four Chapters. Many of the problems of the physicist involve one unknown only, and the first four Chapters contain all the theory that has to be considered in the discussion of such problems. The subject of Chapter VII, the adjustment of conditioned observations, has only been outlined very briefly. The fuller development of the subject, which forms the basis of the adjustment of triangulations, will be found in the works to which reference is made at the end of Chapter VII. The last four Chapters can only be regarded as mere introductions to the subjects discussed, but it was thought that their inclusion in a textbook on Least Squares would be an advantage.

I have to acknowledge my indebtedness to Mr F. J. M. Stratton, of Gonville and Caius College, Cambridge, to whose University lectures I owe most of my knowledge of the subjects discussed in this book, and upon whose notes I have drawn freely. I have also to thank Professor Eddington for many useful suggestions made while the book was in manuscript form, and for permission to extract from his lecture notes a number of interesting examples as well as some portions of the theoretical treatment.

I cannot express adequately my debt to the Cambridge University Press, for the extreme care shown in passing the book through the proof stage. Owing to my being abroad at the time, I was not able to devote as much time as was desirable to the reading of proofs, and but for the unfailing vigilance of the Press, many errors would have been allowed to pass into the text.

DAVID BRUNT.

METEOROLOGICAL SECTION, R.E. G. H. Q. November 23, 1916.

TABLE OF CONTENTS

CHAPTER I

ERRORS OF OBSERVATION

The nature of errors of observation	111	32	12	 *:	10	1993	25	1
Frequency curves	2.					1.00		6
Accuracy of the arithmetic mean		10		20	÷.	1.20	1	9

CHAPTER II

THE LAW OF ERROR

Hagen's proo	f of (Jauss's	err	or lav	Ν.	- X	- 19 -	24	ŝć	100 C	24	20	11
Thomson and	I Tai	t's pro	of	38				0.000	10		1.40	45	14
Generalised f	orm (of Hag	en's	proo	f.							40	15
Form of the									8				18
The arithmet	ic m	ean	¥.,				L Ř.		÷.		1		21
Derivation of	the n	ormal l	aw c	ferro	rst	from	the pr	inciple	of t	he ar	ithme	tie	
теми .	4		ŝ.	×	.		£Q.		φĉ,	18	24		22
Law of error	of a	linear	fun	etion	of	two	indep	endent	qu	antiti	es.	32	24
The median	æ		13	4	-			1 3	÷.		3.4		27
Examples .												43	28
References .												-	28

CHAPTER III

THE CASE OF ONE UNKNOWN

Measures of precision	- 65	÷.	2.4	1			96) 196	38	5 -	100 C	29
Evaluation of h and r											
Comparison of a set of	obse	rvati	ions w	vith	theory		*:			+1	33
Evaluation of μ .											33
Probable error and mer	in sq	uare	error	of	the ari	thm	etie	mean			36
Probable error of a line	car fu	incti	on.	1			1		1.2	10	36
Probable error of the a	rithn	actic	mean	1 20	×.	4	10			10	37
Peters' formula for r											38

CONTENTS

											1	AGE
Examples of the	ho adjt	istinen	t of	observa	tion	ns of	one	uukn	own	and in		39
Probable error	of any	functio	m of	a numl	er	of inc	lepen	dent	quar	tities	÷.	48
Examples .										3 8		49
Errors due to	separati	ble cat	ises	8	1			13		÷		50
Probable error	when	a syst	emat	ic error	e is	pres	ent	28	1.00			51
Correction of								prob	able	error	of	
observation					1		10000-00 A		1.01			53
Precision of th	e prob	able er	TOP	ų.	4	12	12	235	1.1		14	54
Comparison of	· · · · · · · · · · · · · · · · · · ·			for r	12		121	- 22	727	40		58

CHAPTER IV

OBSERVATIONS OF DIFFERENT WEIGHT

The weighting of observations	+	1	135	43	3	2.0	÷8		60
Methods of weighting	4	19	• 3	×.		3431	•2		.63
Alternative method of evaluating	the	DAAR	ision	of	the we	sighte	ed me	an	
when weighting according to	prot	able	errot	ъ.					67
Examples			1.00			1.7			69
Miscellaneous Examples involving	one	auk	nown	18	62	1.0	2	1	72

CHAPTER V

THE GENERAL PROBLEM OF THE ADJUSTMENT OF INDIRECT OBSERVATIONS INVOLVING SEVERAL UNKNOWN QUANTITIES

Statement of the problem	(R	12002		38		*3		75
Formation of the normal equations				œ		• •		77
Independence of the normal equations				8		-		79
Checks on the formation of the normal	l eq	uatio	ns	<u>.</u>	16	2	-	80
Examples of the formation of normal of	qua	tions	- 22	2	33 4	4		82
Solution of the normal equations ,	÷.		80					88

CHAPTER VI

EVALUATION OF THE MOST PROBABLE VALUES OF THE UNKNOWNS, THEIR WEIGHTS AND PROBABLE ERRORS

Gauss's method of substitution	Se	82	$\mathbf{k}^{(i)}$	*	12	12		90
Checks in computation	×	26	•	<u>45</u>				91
Form of solution	э:							94
The Doolittle method of solution								96
The method of determinants .	1	- ä.,						99
Probable error of an observations	l o	quatic	m of	unit	weig	tht		100
Evaluation of probable errors of	the	unkı	iowns	1.2				103

viii

CONTENTS

Evaluation	of the	weig	data (f .z.,	y, z,	etc.						PAGE 105
Examples -											Q	107
Alternative	methe	od of	findi	ag th	e we	ights	of	the n	inkno	wns	£	108
Alternative												113
Alternative				1.12		1		_				

Probable error of any function of the unknowns		116
Normal place method in the formation of observational equations		117
Testing the results of the least square solution for unusual errors, a	and	
for systematic or constant errors		118
Miscellaneous Examples	13	120

CHAPTER VII

THE ADJUSTMENT OF CONDITIONED OBSERVATIONS

Statement of t	the pr	oblem	20	3.07	80	32		1 02	292	2.9	20	124
Direct solution	by s	abstitu	tion	S.,		£	8				-	125
Method of une	letern	nined n	nultip	liers	or c	orrela	ates	1	26		- 22	127
The precision	of the	unku	IWHS	34	÷.	4	23	23	÷		42	128
References	s - 19	88 83	24		12	19	24	83	×		÷	128

CHAPTER VIII

THE REJECTION OF OBSERVATIONS . . . 129

CHAPTER IX

ALTERNATIVES TO THE NORMAL LAW OF ERRORS

Some statistical terms .	1.5	100		se.	- 00		*			133
The methods of moments			5	4					сų,	136
Pearson's curves			. 2	2	- 5	<u>_</u>	12			138
Integration of the different Use of the series	tial e	quati	on	:	8	•) ;	18	+	141
$y = A_0 \phi(x)$) + 1	l₃φ‴(x) +	$A_{4}\phi^{i}$	v(x).	+ etc.				145

CHAPTER X

CORRELATION

Adjustment of the line	of	regressio	m by	the	met	hod	of	least	squares		152
The contingency table	÷.			6 3		•	\propto	(e)	- ×		150
A simple example .	\mathbb{R}^{2}	143 1	93 - S	8 3	6	2	- 12	1.	- A	÷	148