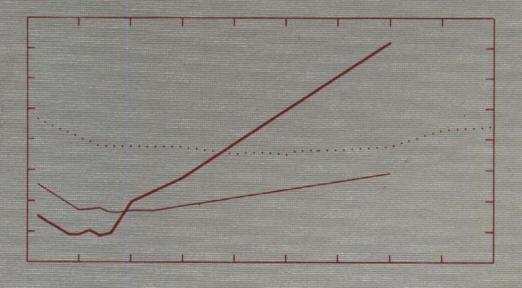
Lecture Notes in Computer Science

848

Arnold R. Krommer Christoph W. Ueberhuber

Numerical Integration

on Advanced Computer Systems





Contents

I	Inti	roduction	1						
1	App	Applications of Numerical Integration 5							
	1.1		6						
			6						
		1.1.2 Computation of Stochastic Quantities							
		1.1.3 Bayesian Statistics							
	1.2	Integral Transforms							
		1.2.1 Fundamentals							
		1.2.2 Application to Differential Equations							
		1.2.3 Finite Transforms and Fourier Series							
		1.2.4 Computational Aspects							
	1.3	Finite Element Methods							
		1.3.1 Variational Equations							
	4	1.3.2 Galerkin Method							
		1.3.3 Fundamentals of Finite Element Methods							
	1.4	Boundary Integral Methods							
		1.4.1 Boundary Integral Equations							
		1.4.2 Collocation Methods							
2	Fun	damentals of Numerical Integration							
	4.1	megration roblems							
	2.2	Integration Methods							
	2.3	Conditioning of Integration Problems							
	2.4	Inherent Uncertainty of Numerical Integration							
I	M	athematical Aspects 35							
3	Inte	egrals with the common and a single conviction of the control of t							
	3.1								
		3.1.1 One Dimension							
		3.1.2 Multiple Dimensions							
	3.2	Improper Integrals							
		3.2.1 One-Dimensional Improper Integrals							

	CONTENTS
X	

				41
		3.2.2	Multi-Dimensional Improper Integrals	41
	3.3	Special	Types of Integrals	42
	3.4	Integra	tion Regions	
	3.5	Woight	Functions	45
	3.6	The Pr	eprocessing of Integrals	47
		3.6.1	The complete of Internals	47
		3.6.2	Decomposition of Integration Regions	54
		3.6.3	Iteration of Integrals	55
4	Uni	variate	Integration Formulas	57 57
	4.1	Constr	uction of Quadrature Formulas	57
		4.1.1		60
		4.1.2	Formula Construction by Approximation	64
		4.1.3	Formula Construction by Acceleration	66
		4.1.4	Transformation of Quadrature Formulas	67
	4.2	Simple	O I I I I I I I I I I I I I I I I I I I	68
		4.2.1	Extraction of the contract of	70
		4.2.2		70
		4.2.3		73
		4.2.4	O Name Cotos Formulas	74
		4.2.5	. O . D	75
		4.2.6	Gauss Formulas	78
		4.2.7	D 1 I Tabatta Formulas	10
		4.2.8	- TT 1 D	
	4.3	Comp	Gauss-Kronrod Formulas oound Formulas Compound Trapezoidal Rule IMT Formulas	82
		4.3.1	Compound Trapezoidal Rule	84
		4.3.2	IMT Formulas	85
	4.4	Roml	perg Formulas	. 87
	4.5	Nonli	IMT Formulas	. 01
	5 M	ultivar	iate Integration Formulas	91 . 92
	5.1	Cons	truction Principles	. 92
		5.1.1	Riemann Sums	. 92
		5.1.2		93
		5.1.3	Construction by Iransion	. 94
		5.1.4	Construction by Iteration	. 0
		5.1.5	Construction by Decomposition	
	5.	2 Poly	nomial Rules	
		5.2.1	Multivariate Polynomials	10
		5.2.2	Construction of Interpolatory Formulas	11
		5.2.3	Simple Interpolatory Formulas	11
		5.2.	Compound Formulas	. 11
	5.	.3 Low	-Discrepancy Formulas	11
		5.3.	1 Desidiate in the second seco	. 11

CONTENTS	x
	25.

			0 8: 1 17 8:	
		5.3.2	One-Dimensional Low-Discrepancy Sequences	
		5.3.3	Multi-Dimensional Low-Discrepancy Sequences	. 128
	5.4		orandom Methods	. 134
		5.4.1	Basic Monte Carlo Techniques	. 134
		5.4.2	Variance Reduction Schemes	. 137
		5.4.3	Generation of Pseudorandom Numbers	
		5.4.4	Generation of Uniform Random Numbers	
		5.4.5	Generation of Non-Uniform Random Numbers	. 144
	5.5	Lattice	Rules	
		5.5.1	Formula Construction by Harmonic Analysis	
		5.5.2	Basic Definitions	. 149
		5.5.3	Practical Representation of Lattice Rules	. 151
		5.5.4	Error Analysis of Lattice Rules	. 152
		5.5.5	Efficiency of Lattice Rules	. 159
	5.6	Variou	s Special Methods	. 161
			and second it is secured as a wind in the second in the se	
I	II A	lgorit	hmic and Computational Aspects	163
6			Algorithms	165
0			Estimation	100
	0.1	6.1.1		
		6.1.2	Fundamental Uncertainty	
		6.1.3	Use of Two Integration Formulas with Different Accuracy	
	0.00	6.1.4	Use of Null Rules	. 169
			Use of the Same Formula on Different Subdivisions	
	6.0	6.1.5	Use of Randomized Formulas	
	6.2		ing Strategy	
		6.2.1	Efficiency Assessment	
		6.2.2	Non-Adaptive Algorithms	
	0.0	6.2.3	Adaptive Algorithms	
	6.3	Reliabi	llity Enhancement	. 184
		6.3.1	Noise Detection	
	0.4	6.3.2	Detection of Non-Integrable Functions	
	6.4		ncy Enhancement	. 187
		6.4.1	Extrapolation in Non-Adaptive Algorithms	. 187
	2	6.4.2	Extrapolation in Adaptive Algorithms	. 187
	6.5	Integra	ation of Multiple Integrands	. 190
7	Load	d Distr	ribution	193
01	7.1		Load Distribution	1.000
			nic Load Distribution	
	0	7.2.1	Dynamic Load Balancing Algorithms	
		7.2.2	Asynchronous Single Task Pool Methods	
		7.2.3		
		1.2.0	Synchronous Single Task Pool Methods	. 200

xii CONTENTS

		7.2.4	Multiple Task Pool Methods	01
		/		
		7.2.5	Synchronous Multiple Task Pool Methods 2	05
		7.2.6	Asynchronous Multiple Task Pool Methods 2	206
		7.2.7	Hierarchical Methods	209
8	Pote	ntial P	arancisii iii iiivograma iiivograma	11
	8.1	Integral	nd Level	211
	8.2	Global	Extrapolation Level	214
	8.3	Subdivi	sion Level	215
	8.4	Subregi	on Level	218
	8.5	Local E	Extrapolation Level	219
	8.6	Integra	tion Formula Level	219
	8.7	Integra	tion Formula Level	221
9			Ton Sometimes and an arrangement	
	9.1		uent Parts of Parallel Tasks	
	9.2		nance Characteristics of Parallel Tasks	
			Algorithmic Efficiency	
			Degree of Parallelism	
		9.2.3	Kind of Parallelism	
		9.2.4	Predictability of Execution Times	
		9.2.5	Locality of Reference	229
10	Pra	ctical I	Parallelization of Integration Algorithms 2	233
				233
				234
		10.1.2	DIMID Compaters	235
		10.1.3	MIMD Systems	235
	10.2	Vector	ization of Integration Methods	236
		10.2.1	Integrand Evaluation Level	236
		10.2.2	Integration Formula Level	237
		10.2.3	Integrand Level	237
		10.2.4	Multiple Level Vectorization	237
	10.3	Paralle	elization of Integration Methods	238
		10.3.1	Integration Formula Level	238
		10.3.2	Subregion Level	200
			Subdivision Level	
			Subdivision and Subregion Level	
			Subdivision, Subregion, and Integration Formula Level	
			rization and Parallelization of Extrapolation Methods	
			rization and Parallelization of Abscissa Computations	
	10.6	Vector	rization and Parallelization of Reduction Operations	254

CONTENTS	xii
11. Parallel Data Management 11.1 Data Structures for Global Subdivision Strategies 11.1.1 Heaps 11.1.2 Other Implementations of Priority Queues 11.2 Concurrent Access to Data Structures 11.2.1 Concurrent Access to Priority Queues 11.2.2 New Types of Data Structures	259 263 269 270
IV Software Aspects	277
12.1 Assessment Criteria 12.1.1 Reliability 12.1.2 Performance 12.1.3 Portability 12.2 Techniques of Assessment 12.2.1 Test Batteries and Performance Profiles 12.2.2 Fundamental Approaches to Assessing Numerical Integration Software	280 283 283 286
13 Architecture Adaptive Integration Algorithms 13.1 Required Information	293 294 300
Glossary of Notation	303
Bibliography	309
Authors	329
Index	334

Lecture Notes in Computer Science

This series reports new developments in computer science research and teaching, quickly, informally, and at a high level. The timeliness of a manuscript is more important than its form, which may be unfinished or tentative. The type of material considered for publication includes

- drafts of original papers or monographs,
- technical reports of high quality and broad interest,
- advanced-level lectures.
- reports of meetings, provided they are of exceptional interest and focused on a single topic.

Publication of Lecture Notes is intended as a service to the computer science community in that the publisher Springer-Verlag offers global distribution of documents which would otherwise have a restricted readership. Once published and copyrighted they can be cited in the scientific literature.

Manuscripts

Lecture Notes are printed by photo-offset from the master copy delivered in camera-ready form. Manuscripts should be no less than 100 and preferably no more than 500 pages of text. Authors of monographs and editors of proceedings volumes receive 50 free copies of their book. Manuscripts should be printed with a laser or other high-resolution printer onto white paper of reasonable quality. To ensure that the final photo-reduced pages are easily readable, please use one of the following formats:

Font size	Printing area		Final size	
(points)	(cm)	(inches)	(%)	
10	12.2 x 19.3	4.8 x 7.6	100	
12	15.3 x 24.2	6.0 x 9.5	80	

On request the publisher will supply a leaflet with more detailed technical instructions or a T_EX macro package for the preparation of manuscripts.

Manuscripts should be sent to one of the series editors or directly to:

Springer-Verlag, Computer Science Editorial I, Tiergartenstr. 17, D-69121 Heidelberg, Germany

