*22 Divided differences. The divided difference of order $k > 1$ of $f(x)$ is defined by

$$f[a_1, \ldots, a_k] = \frac{f[a_2, \ldots, a_k] - f[a_1, \ldots, a_{k-1}]}{a_k - a_1} \qquad \text{with } f[a_1] = f(a_1)$$

(a) Prove that

$$f[a_1, \ldots, a_k] = \sum_{i=1}^{k} \frac{f(a_i)}{(a_i - a_1) \cdots (a_i - a_{i-1})(a_i - a_{i+1}) \cdots (a_i - a_k)}$$

and thus deduce that the order of the arguments in a divided difference is immaterial.
   (b) Use the data of Example 3.1 to generate a divided-difference table analogous to the difference table of Fig. 3.1.
   (c) Show that

$$f[a_1, \ldots, a_{k-1}, x] = f[a_1, \ldots, a_k] + (x - a_k)f[a_1, \ldots, a_k, x]$$

and use this result to derive the formula

$$f(x) = f[a_1] + (x - a_1)f[a_1, a_2] + (x - a_1)(x - a_2)f[a_1, a_2, a_3]$$
$$+ \cdots + (x - a_1)(x - a_2) \cdots (x - a_{n-1})f[a_1, \ldots, a_n] + E(x)$$

where $\qquad\qquad E(x) = p_n(x)f[a_1, \ldots, a_n, x]$

This formula is called *Newton's divided-difference interpolation formula.*
   (d) Deduce from part (c) that $(x - a_k)f[a_1, \ldots, a_n, x] \to 0$ as $x \to a_k$, $k = 1, \ldots, n$.
   (e) Use this result to show that this formula must be algebraically equivalent to the Lagrangian interpolation formula which uses the tabular points $a_1, \ldots, a_n$. Thus deduce that

$$f[a_1, \ldots, a_n, x] = \frac{1}{n!}f^{(n)}(\xi)$$

where ξ is in the interval spanned by $a_1, \ldots, a_n$ and x.
   (f) Use the results of parts (c) and (e) to show that when $a_i \to a$, $i = 1, \ldots, n$, the Newton divided-difference formula and therefore the Lagrangian formula are both equivalent to a Taylor series with remainder.
   (g) Use Newton's divided-difference formula and the table of part (b) to approximate ln .60. Compare the result with Example 3.1.
   (h) When the tabular points are equally spaced, show that

$$f[a_1, \ldots, a_k] = \frac{1}{(k-1)!h^{k-1}} \Delta^{k-1} f_1$$

and thus use part (c) to derive Newton's forward formula.

Numerical Calculus

Germund Dahlquist,Åke Björck

Numerical Calculus:

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Numerical Methods for Fractional Calculus Changpin Li,Fanhai Zeng,2015-05-19 Numerical Methods for Fractional Calculus presents numerical methods for fractional integrals and fractional derivatives finite difference methods for fractional ordinary differential equations FODEs and fractional partial differential equations FPDEs and finite element methods for FPDEs The book introduces the basic definitions and propertie Fractional Calculus: Models And Numerical Methods Dumitru Baleanu,Kai Diethelm,Enrico Scalas,Juan J Trujillo,2012-01-27 The subject of fractional calculus and its applications that is convolution type pseudo differential operators including integrals and derivatives of any arbitrary real or complex order has gained considerable popularity and importance during the past three decades or so mainly due to its applications in diverse fields of science and engineering These operators have been used to model problems with anomalous dynamics however they also are an effective tool as filters and controllers and they can be applied to write complicated functions in terms of fractional integrals or derivatives of elementary functions and so on This book will give readers the possibility of finding very important mathematical tools for working with fractional models and solving fractional differential equations such as a generalization of Stirling numbers in the framework of fractional calculus and a set of efficient numerical

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either a single term course or a year long sequence It is suitable for undergraduate students in mathematics science and engineering Ample material is presented so that instructors will be able to select topics appropriate to their needs

Fractional Calculus: Models And Numerical Methods (Second Edition) Juan J Trujillo,Enrico Scalas,Kai Diethelm,Dumitru Baleanu,2016-09-15 This book will give readers the possibility of finding very important mathematical tools for working with fractional models and solving fractional differential equations such as a generalization of Stirling numbers in the framework of fractional calculus and a set of efficient numerical methods Moreover we will introduce some applied topics in particular fractional variational methods which are used in physics engineering or economics We will also discuss the relationship between semi Markov continuous time random walks and the space time fractional diffusion equation which generalizes the usual theory relating random walks to the diffusion equation These methods can be applied in finance to model tick by tick log price fluctuations in insurance theory to study ruin as well as in macroeconomics as prototypical growth models All these topics are complementary to what is dealt with in existing books on fractional calculus and its applications This book will keep in mind the trade off between full mathematical rigor and the needs of readers coming from different applied areas of science and engineering In particular the numerical methods listed in the book are presented in a readily accessible way that immediately allows the readers to implement them on a computer in a programming language of their choice The second edition of the book has been expanded and now includes a discussion of additional newly developed numerical methods for fractional calculus and a chapter on the application of fractional calculus for modeling processes in the life sciences   Numerical Methods for Ordinary Differential Equations David Griffiths,Desmond J. Higham,2010-11-25 Numerical Methods for Ordinary Differential Equations is a self contained introduction to a fundamental field of numerical analysis and scientific computation Written for undergraduate students with a mathematical background this book focuses on the analysis of numerical methods without losing sight of the practical nature of the subject It covers the topics traditionally treated in a first course but also highlights new and emerging themes Chapters are broken down into lecture sized pieces motivated and illustrated by numerous theoretical and computational examples Over 200 exercises are provided and these are starred according to their degree of difficulty Solutions to all exercises are available to authorized instructors The book covers key foundation topics o Taylor series methods o Runge Kutta methods o Linear multistep methods o Convergence o Stability and a range of modern themes o Adaptive stepsize selection o Long term dynamics o Modified equations o Geometric integration o Stochastic differential equations The prerequisite of a basic university level calculus class is assumed although appropriate background results are also summarized in appendices A dedicated website for the book containing extra information can be found via www springer com

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