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Intro to numerical analysis pdf

Numerical analysis is an increasingly important relationship between pure mathematics and its application in science and technology. This textbook provides an introduction to justification and development of constructive methods that provide fairly accurate estimates for numerical problem solutions, and analysis of the influence of errors in data, limited precision calculations, and forecast formulas on results, problem formulations and method options. It also serves as an introduction to scientific programming at MATLAB, including many simple and difficult exercises, theoretical and computational. A unique feature of the book is the development of interval analysis as a tool for rigorous computing and computer-assisted evidence, along with traditional materials. Includes many matlab exercises Introducing interval analysis Can be used for courses in mathematics, engineering, and physicsRead more '... it's very valuable in setting up a course on Numerical Analysis and it's very easy to read.' Thomas Sonar, Zentralblatt MATH'This is highly recommended reading for all undergraduate students whose courses require serious understanding and implementation of numerical analysis.' The Mathematical GazetteSee further review Customer reviews Being the first to review log in to review Date Published: October 2001format: Paperbackisbn: 9780521336109length: 366 page dimensions: 229 x 152 x 21 mmweight: 0.54kgcontains: 30 b/ill wus. availability: Available 1. Numeric evaluation of expression 2. Linear system of equations 3. Interpolation and numerical differentiation 4. Numerical integration 5. Univariate nonlinear equation 6. System of nonlinear equations. See InsideArnold Neumaier, Universität Wien, Austria The mathematics field of the Babel clay tablet YBC 7289 (c. 1800–1600 BC) with annotations. The estimated square root of 2 is four sexagesimal numbers, which is about six decimal digits. 1 + 24/60 + 51/602 + 10/603 = 1.41421296... [1] Numerical analysis is an algorithmic study that uses numerical estimates (as opposed to symbolic manipulation) for mathematical analysis problems (as distinguished from discrete mathematics). Numerical analysis naturally finds applications in all fields of engineering and physics, but in the 21st century also life sciences, social sciences, medicine, business and even art have adopted the element of scientific computing. The growth of computing power has revolutionized the use of realistic mathematical models in science and engineering, and fine numerical analysis is needed to implement the detailed models of this world. For example, common differential equations appear in celestial mechanics (predicting the movement of planets, stars, and galaxies); numerical linear algebra is important for data analysis; [2] [3] [4] Differential equations and the Markov chain are essential in simulating living cells for medicine and biology. Before the advent of modern computers, numerical methods often relied on hand interpolation formulas applied to data from large print tables. Since the mid-20th century, computers calculated the necessary functions instead, but many of the same formulas can still be used as part of software algorithms. [5] The numerical point of view returns to the earliest mathematical writings. Tablets from the Yale Babylonian Collection (YBC 7289), give a sexagesimal numerical estimate of the square root 2, the diagonal length in the unit box. Numerical analysis continues this long tradition: rather than an exact symbolic answer, which can only be applied to real-world measurements with translation to digits, it provides an approximate solution within the specified error limits. General introduction The overall purpose of the field of numerical analysis is design and analysis techniques to provide forecasts but accurate solutions to hard problems, a variety suggested by the following: Advanced numerical methods are essential in making numerical weather predictions feasible. Calculating the trajectory of a spacecraft requires an accurate numerical solution of the usual differential equation system. Car companies can improve the safety of their vehicle accidents by using computer simulations of car accidents. Such simulations basically consist of solving partial differential equations numerically. Hedge funds use tools from all areas of numerical analysis to try to calculate the value of stocks and derivatives more precisely than other market participants. Airlines use advanced optimization algorithms to decide ticket prices, aircraft and crew assignments, and fuel needs. Historically, such algorithms were developed in the field of overlapping research operations. Insurers use numerical programs for actuarial analysis. Another section of this section outlines some important themes of numerical analysis. History The field of numerical analysis preceded the invention of modern computers for centuries. Linear interpolation was used over 2000 years ago. Many great mathematicians in the past were preoccupied by numerical analysis,[5] as is evident from the names of important algorithms such as the Newton method, the Lagrange polynomial interpolation, gaussian elimination, or the Euler method. To facilitate computing by hand, led books are produced with formulas and data tables such as interpolation points and function coefficients. Using this table, often calculated to 16 decimal places or more for multiple functions, one can look up values to plug into a given formula and achieve an excellent numeric estimate of some Canonical work this field is a NIST publication edited by Abramowitz and Stegun, a 1000-plus page book of a large number of commonly used formulas and functions and their value at many points. Function values are no longer very useful when a computer is available, but a large list of formulas can still be very useful. Mechanical calculators were also developed as a tool for hand computing. This calculator evolved into an electronic computer in the 1940s, and it was later discovered that it was also useful for administrative purposes. But computer discovery also affects the field of numerical analysis,[5] because now longer and more complex calculations can be made. Direct and iterative method Consider troubleshooting 3x3 + 4 = 28 for an unknown quantity of x. Direct method 3x3 + 4 = 28. Subtract 4 3x3 = 24. Divided by 3 x3 = 8. Take the root cube x = 2. For iterative methods, apply the biseksi method to f(x) = 3x3 − 24. The starting value is a = 0, b = 3, f(a) = −24, f(b) = 57. Iterative method a b mid f(mid) 0 3 1.5 −13.875 1.5 3 2.25 10.17... 1.5 2.25 1.875 −4.22... 1.875 2.25 2.0625 2.32... From this table it can be concluded that the solution is between 1.875 and 2.0625. The algorithm can return any number in that range with an error of less than 0.2. Socialized and numerical integration In a two-hour race, the speed of the car is measured at three instants and recorded in the following table. Time 0:20 1:00 1:40 km / h 140 150 180 A discrete will say that the speed of the car is constant from 0:00 to 0:40, then from 0:40 to 1:20 and finally from 1:20 to 2:00. For example, the total distance traveled in the first 40 minutes is approximately (2/3 hour × 140 km/h) = 93.3 km. This will allow us to estimate the total distance performed as 93.3 km + 100 km + 120 km = 313.3 km, which is an example of numerical integration (see below) using the number of Riemann, since displacement is integral to speed. Bad condition problem: Take the function f(x) = 1/(x − 1). Note that f(1.1) = 10 and f(1.001) = 1000: changes in x less than 0.1 change to a change in f(x) of nearly 1000. Evaluating f(x) near x = 1 is an unconditioned issue. Well-conditioned problem: Instead, evaluating the same function f(x) = 1/(x − 1) near x = 10 is a well-conditioned problem. For example, f(10) = 1/9 ≈ 0.111 and f(11) = 0.1: simple changes in x cause simple changes in f(x). The method instantly calculates the solution to the problem in a limited number of steps. These methods will provide the right answers if they are carried out in infinite precision arithmetic. Examples include Gaussian elimination, QR factorization methods for solving linear equation systems, and linear programming methods In practice, limited precision is used and the result is a correct solution (assuming stability). Unlike the direct method, the iterative method is not expected to end in a limited number of steps. Starting from the initial guess, the iterative method forms successive estimates that merge with the right solution only within limits. Convergence tests, often involving residuals, are determined to decide when a fairly accurate solution has (hopefully) been found. Even using infinite precision arithmetic this method will not achieve the solution in a limited number of steps (in general). Examples include newtonian methods, biseksi methods, and Jacobi iterations. In computational matrix algebra, repetitive methods are generally required for major problems. [7][8][9] Iterative methods are more common than direct methods of numerical analysis. Some methods are direct in principle but are usually used as if they were not, for example GMRES and conjugation gradient methods. For this method the number of steps required to get the right solution is so large that the estimate is accepted in the same way as for the iterative method. Discrete Furthermore, ongoing problems sometimes have to be replaced by discrete problems whose solutions are known to estimate that of continuous problems; this process is called 'discretization'. For example, the solution of differential equations is a function. This function must be represented by a limited amount of data, for example by its value at a limited number of points in its domain, even if it is a continuum. Generation and error propagation Error studies form an important part of numerical analysis. There are several ways in which errors can be introduced in problem solutions. The Round-off Error Round-off appears because it is impossible to represent all the real numbers exactly on machines with limited memory (which is what all digital computers are practical). Crop and discretization errors Tedizing errors are performed when iterative methods are stopped or mathematical procedures are estimated, and approximate solutions differ from the right solutions. Similarly, discretization induces discrete errors because discrete problem solutions do not coincide with ongoing problem solutions. For example, in the iteration in the sidebar to calculate a solution of 3 x 3 + 4 = 28 {\displaystyle 3x^{3}+4=28} , after 10 or more iterations, it can be concluded that the root is about 1.99 (for example). Therefore, there was a 0.01 withholding error. Once the error is generated, it will generally propagate through the calculation. For example, it has already noted that the operation + on the calculator (or computer) does not exist. This follows that the calculation of type a + b + c + d + e {\displaystyle a+b+c+d+e} even more does not exist. T-cutting error created when procedures are estimated. To integrate the function is exactly necessary to find an infinite number of trapezoids, but numerically only a limited number of trapezoids can be found, and hence the approximate mathematical procedure. Similarly, to distinguish functions, differential elements are close to zero but numerically only a limited value of differential elements can be selected. Numerical stability and well-posed problems Numerical stability is the idea in numerical analysis. The algorithm is called 'numerically stable' if the error, whatever the cause, does not grow to be much larger during calculation. [10] This happens if the problem is 'well conditioned', meaning that the solution changes only in small amounts if the problem data is changed by a small amount. [10] Conversely, if the problem is 'unconditioned', then a small error in the data will grow into a big mistake. [10] The original problem and the algorithm used to solve the problem can be 'well conditioned' or 'unconditioned', and any combination is possible. So algorithms that solve well-conditioned problems may be numerically stable or numerically unstable. The art of numerical analysis is finding stable algorithms to solve well-posed mathematical problems. For example, calculating the square root of 2 (which is approximately 1.41421) is a well-posed problem. Many algorithms solve this problem by starting with an initial estimate of x0 to 2 {\displaystyle {\sqrt {2}}} , e.g. x0 = 1.4, and then computational increase in x1, x2, etc. guesses. One such method is the famous Babylonian method, given by xk+1 = xk/2 + 1/xk. Another method, called the 'X method', is administered by xk+1 = (xk2 − 2)2 + xk. [note 1] Several iterations of each scheme are calculated in the table form below, with initial guesses x0 = 1.4 and x0 = 1.42. Babel Method X Method X x0 = 1.4 x0 = 1.42 x0 = 1.4 x0 = 1.42 x1 = 1.4142857... x1 = 1.41422535... x1 = 1.4016 x1 = 1.42026896 x2 = 1.414213564... x2 = 1.41421356242... x2 = 1.4028614... x2 = 1.42056... ... ... x1000000 = 1.41421... x27 = 7280.2284... Observe that the Babylonian method meets quickly regardless of the initial guess, whereas method X meets very slowly with the initial guess x0 = 1.4 and deviates for the initial guess x0 = 1.42. Therefore, the Babylonian method is numerically stable, while method X is numerically unstable. Numeric stability is affected by the number of significant digits that the machine continues to maintain, if the machine is used that stores only the four most significant decimal digits, a good example of the loss of significance can be given by these two equivalent functions f (x) = x (x + 1 − x) and g (x) = x + 1 + x . We're going to have to wait and see. {x}} \right){\text{ and }}g(x)={\frac {x}{{\sqrt {x+1}}+{\sqrt {x}}}}.} Comparing results f (500) = 500 ((− 500) = 500 (22.38 − 22.36) = 500 (0.02) = 10 {\displaystyle f(500)=500\left({\sqrt {501}}-{\sqrt {500}}\right)=500\left(22,38-22,36\right)=500(0.02)=10} and g (500) = 500 501 + 500 = 500 22.538 + 22.36 = 500 44.74 = 11.17 {\displaystyle {\begin{aligned}{3}g(500)&={\frac {500}{{\sqrt {501}}+{\sqrt {500} {3}}}}\\&{\frac {500}{22.38+22.36}}\\\\\\frac {500}{44.74}}=11.17\end{aligned}}} by comparing the two results above , it is clear that the loss of significance (caused here by the 'catastrophic cancellation') has a huge effect on the outcome, although both functions are equivalent, as shown below f (x) = x (x + 1 − x) = x (x + 1 − x) x + 1 + x + 1 + x = x (x + 1) 2 − (x) 2 x + 1 + x = x + 2 − x + 1 + x = x = x 1 x + 1 + x = x + 1 + x = g (x) {\displaystyle {\begin{aligned}{4}f(x)&x\left({\sqrt { x+1}}-{\sqrt {x}}\right)\\&x\left ({\sqrt {x+1}}-{\sqrt {x}}\right){\frac {{\sqrt {x+1}}+{\sqrt {x}}}{{\sqrt {x+1}}+{\sqrt {x}}}}\\\x{\frac {({\sqrt {x+1}})^{2}-({\sqrt {x}})^{2}}{{\sqrt {x+1}}+{\sqrt {x}}}}\\\x{\frac {x+1-x}{{\sqrt {x+1}}+{\sqrt {x}}}}\\\\\\x{\frac {1}{{\sqrt {x+1}}+{\sqrt {x}}}}\\\\\\frac {x}{{\sqrt {x+1}}+{\sqrt {x}}}}\\\\g(x)\end{aligned}}} Desired value , calculated using infinite precision, is 11.174755 ... Examples are modifications taken from Mathew; Numeric method using Matlab, 3rd ed. Fields of study The field of numerical analysis includes many sub-disciplines. Some of the main functions are:: Observing that the temperature varies from 20 degrees Celsius at 1:00 to 14 degrees at 3:00, linear interpolation of this data will conclude that it is 17 degrees at 2:00 and 18.5 degrees at 1:30 pm. Extrapolation: If a country's gross domestic product had grown by an average of 5% per year and 100 billion last year, it might have extrapolated that it would have been 105 billion this year. Regression: In linear regression, given n points, a calculated line passes as close as possible to that n point. Optimization: Let's say lemonade sold in place of lemonade, at $1 197 a glass of lemonade can be sold per day, and that for every increase of $0.01, one glass less lemonade will be sold per day. If $1,485 can be charged, the profit will be maximized but due to constraints it will have to charge an overall amount of cents, charging $1.48 or $1.49 per glass both of which will generate a maximum income of $220.52 per day. Differential equation: If 100 fans are set to blow air from one end of the room to the other end of the room and then feathers are dropped into the wind, what happens? Feathers will follow the air currents, which may be very complex. One estimate is to measure the speed at which the air blows near the plume every second, and advance the simulated plume as if moving in a straight line the same speed for one second, before measuring the wind Again. This is called the Euler method for solving ordinary differential equations. One of the simplest problems is the evaluation of functions at a certain point. The easiest approach, simply plugging in the numbers in the formula is sometimes not very efficient. For polynomials, a better approach is to use the Horner scheme, since it reduces the number of multiplications and additions required. Generally, it is important to estimate and control round-off errors arising from the arithmetic use of floating points. Interpolation, extrapolation, and regression of Interpolation solve the following problem: given the value of some unknown functions at a number of points, what value has a function at some other point between certain points? Extrapolation is very similar to interpolation, except that now unknown function values at points that are outside the given point must be found. [11] Regression is similar, but takes into account that the data is incorrect. Given some points, and the measurement of the value of some functions at these points (with errors), unknown functions can be found. The least squared method is one way to achieve this. Solving equations and systems of equations Another fundamental problem is calculating the solution of some given equations. Two cases are generally distinguished, depending on whether the equation is linear or not. For example, the equation 2 x + 5 = 3 {\displaystyle 2x+5=3} is lined while 2 x 2 + 5 = 3 {\displaystyle 2x^{2}+5=3} is not. Many efforts have been put in the development of methods for solving linear equation systems. Standard direct methods, i.e. methods that use multiple matrix decompositions are Gaussian elimination, LU decomposition, Kolesky decomposition for symmetrical (or hermitian) and positive-sure matrices, and QR decomposition for non-square matrices. Repetitive methods such as the Jacobi method, the Gauss-Seidel method, successive excessive relaxation and conjugation gradient methods[12] are usually preferred for large systems. Common iterative methods can be developed using matrix separation. Root finder algorithms are used to solve nonlinear equations (they are named so because the root function is an argument in which the function returns zero). If its functions can be differential and its derivatives are known, then newton's method is a popular choice. [14] Linearization is another technique for solving nonlinear equations. Solving eigenvalue or single value problems Some important issues can be expressed in terms of eigenvalue decomposition or single value decomposition. For example, the spectral image compression algorithm[15] is based on single-value decomposition. The appropriate tool in statistics is called analysis of the main components. Optimization Main Article: Optimization issues math asks for points in the the given function is maximized (or minimized). Often, the point must also satisfy some constraints. The optimization field is then divided across multiple subfields, depending on the form of the objective function and its limitations. For example, linear programming relates to the case that objective functions and limitations are linear. A well-known method in linear programming is the simplex method. The Lagrange multiplier method can be used to reduce optimization issues with limits for unaltrained optimization issues. Evaluating integrals Main article: Numeric integration Numeric integration, in some cases also known as numerical quadratic, asks for definite integral values. [16] Popular methods use either newton-cotes formulas (such as the midpoint rule or Simpson rule) or Gaussian quadratic. [17] These methods relied on dividing and conquering strategies, in which integrals in relatively large sets were broken down into integrals on smaller sets. In higher dimensions, where this method becomes very expensive in terms of computational efforts, one can use the Monte Carlo or kuasi-Monte Carlo methods (see Monte Carlo integration[18]), or, in sle large dimensions, lattice methods are rare. Differential Equations Main articles: Numerical common differential equations and partial numerical differential equations Numerical analysis also deals with computational (by way of forecasting) solutions to differential equations, ordinary differential equations and partial differential equations. [19] Partial differential equations are solved by first eliminating equations, bringing them into a subspace of limited dimensions. [20] This can be done by the limited element method,[21][22][23] the limited difference method,[24] or (especially in engineering) the limited volume method. [25] The theoretical justification of this method often involves the theorem of functional analysis. This reduces the problem on algebraic equation solutions. Main articles software: List of numerical analysis software and Numerical analysis software Comparison Since the end of the twentieth century, most algorithms are implemented in various programming languages. The Netlib repository contains a wide collection of software routines for numerical problems, mostly in Fortran and C. Commercial products that apply many different numerical algorithms including IMSL and NAG libraries; an alternative to free software is the GNU Scientific Library. Over the years the Royal Statistical Society published many algorithms in its Applied Statistics (the code for this US function is here); ACM also, in Transactions on Mathematical Software (TOMS code is here). The Naval Surface Warfare Center has published several Library of Mathematics Subroutines (code here). There is some numerical computing such as MATLAB,[26][27][28] TK Solver, S-PLUS, and IDL[29] as well as free and open source alternatives such as FreeMat, Scilab,[30][31] GNU Octave (similar to Matlab), and IT++ (C++ libraries). There are also programming languages such as R[32] (similar to S-PLUS) and Python with libraries such as NumPy, SciPy[33][34][35] and SymPy. Performance varies greatly: while vector and matrix operations are usually fast, scalar loops can vary in speed over order of magnitude. [37] Many computer algebra systems such as Mathematica also benefit from the availability of arbitrary precision arithmetic that can deliver more accurate results. [38] [41] Additionally, any spreadsheet software can be used to solve simple problems related to numerical analysis. Excel, for example, has hundreds of functions available, including for matrices, that can be used in common with its built-in solvers. See also Analysis of computational science Computational Science Arithmetic Intervals List of numerical analysis topics Methods of local linearization Numerical Differentiation Recipe Numerical-numerical computing Computational notes validated ^ This is a fixed point iteration for equations x = (x 2 − 2) 2 + x = f (x) {\displaystyle x=(x^{2}-2)^{2}+x=f(x)} , whose solutions include 2 {\displaystyle {\sqrt {2}}} . Iterations have always moved to the right since f (x) ≥ x {\displaystyle f(x)\geq x} . Therefore x 1 = 1.4 < 2 {\displaystyle x_{1}=1.4<{\sqrt {2}}} gathered and x 1 = 1.42 > 2 {\displaystyle x_{1}=1.42>{\sqrt {2}}} deviated. Reference Excerpt ^ Photo, illustration, and description of the root tablet(2) of the Yale Babylonian Collection ^ Demmel, J. W. (1997). Numerical linear algebra is applied. Siam. ^ Ciarlet, P. G., Miara, B., & Thomas, J.M. (1989). Introduction to algebra and numerical linear optimization. Cambridge University press. ^ Trefethen, Lloyd; Smell III, David (1997). Numerical Linear Algebra (1st ed.). Philadelphia: SIAM. ^ a b c Brezinski, C., & Wuytack, L. (2012). Numerical analysis: Historical development in the 20th century. Elsevier. Saad, Y. (2003). Iterative methods for linear systems are rare. Siam. Hageman, L. A., & Young, D.M. (2012). Applied iterative methods. Courier Company. ^ Traub, J. F. (1982). Iterative method for equation solutions. 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