

NUMERICAL METHODS

C / KAPPA EXAM 12 / 11/19 / 2022 / 20.000

LEAST SQUARES REGRESSION

Goal: minimize the sum of the squares of the residual errors.

Residual: $e_i = y_i - \hat{y}_i$

Sum of Squares: $S = \sum_{i=1}^n e_i^2 = \sum_{i=1}^n (y_i - a_0 - a_1 x_i)^2$

Normal Equations:

$$\frac{\partial S}{\partial a_0} = -2 \sum_{i=1}^n (y_i - a_0 - a_1 x_i) = 0$$

$$\frac{\partial S}{\partial a_1} = -2 \sum_{i=1}^n x_i (y_i - a_0 - a_1 x_i) = 0$$

Matrix form: $\begin{bmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \end{bmatrix}$

STANDARD ERROR:

$$S_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n-2}}$$

$$S_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-2}}$$

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{\sum_{i=1}^n y_i^2}{n-1}}$$

$$S_x = \sqrt{\frac{\sum_{i=1}^n x_i^2}{n-1}}$$

INTERPOLATION

Use a 4th order polynomial

Order	Degree	Nodes	Points
1	1	2	2
2	2	3	3
3	3	4	4
4	4	5	5

Polynomial: $P_n(x) = a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n$

Order: $n=1$ (line), $n=2$ (parabola), $n=3$ (cubic), $n=4$ (quartic)

Turns: $n=1$ (0), $n=2$ (1), $n=3$ (2), $n=4$ (3)

Splices: $P_n = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i}$

POLYNOMIAL QUADRATIC REGRESSION

Goal: minimize the sum of the squares of the residual errors.

Residual: $e_i = y_i - \hat{y}_i$

Sum of Squares: $S = \sum_{i=1}^n (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$

Normal Equations:

$$\frac{\partial S}{\partial a_0} = -2 \sum_{i=1}^n (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0$$

$$\frac{\partial S}{\partial a_1} = -2 \sum_{i=1}^n x_i (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0$$

$$\frac{\partial S}{\partial a_2} = -2 \sum_{i=1}^n x_i^2 (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0$$

Matrix form: $\begin{bmatrix} n & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \\ \sum x_i^2 y_i \end{bmatrix}$

ODE'S

Runge-Kutta Method:

$$y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

Heun's Method:

$$y_{i+1} = y_i + f(x_i, y_i) \Delta x + \frac{1}{2} (f(x_i, y_i) - f(x_{i+1}, y_{i+1})) \Delta x^2$$

Taylor Series:

$$y(x+\Delta x) = y(x) + \Delta x y'(x) + \frac{\Delta x^2}{2} y''(x) + \dots$$

CLASSIC 4th ORDER RUNGE-KUTTA

$$y_{i+1} = y_i + \frac{\Delta x}{4} (k_1 + 2k_2 + 2k_3 + k_4)$$

$k_1 = f(x_i, y_i)$
 $k_2 = f(x_i + \frac{1}{2}\Delta x, y_i + \frac{1}{2}\Delta x k_1)$
 $k_3 = f(x_i + \frac{1}{2}\Delta x, y_i + \Delta x k_2)$
 $k_4 = f(x_i + \Delta x, y_i + \Delta x k_3)$

Local truncation error: $\mathcal{O}(\Delta x^5)$

PDE'S

FINITE DIFFERENCE METHOD

Grid with nodes and boundaries.

Central Difference: $\frac{\partial^2 u}{\partial x^2} \approx \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2}$

EIGEN VALUES

Single 2x2:

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

$$\det(A - \lambda I) = \det \begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} = (a-\lambda)(d-\lambda) - bc = 0$$

$$\lambda^2 - (a+d)\lambda + (ad-bc) = 0$$

$$\lambda = \frac{(a+d) \pm \sqrt{(a+d)^2 - 4(ad-bc)}}{2}$$

RIGHT BOUNDARY B.C.

$$\frac{\partial u}{\partial x} = u_x = \frac{u_{i+1} - u_{i-1}}{2\Delta x}$$

$$u_{i+1} = u_{i-1} + 2\Delta x u_x$$

TOP BOUNDARY B.C.

$$\frac{\partial u}{\partial y} = u_y = \frac{u_{i+1} - u_{i-1}}{2\Delta y}$$

$$u_{i+1} = u_{i-1} + 2\Delta y u_y$$

LEFT BOUNDARY B.C.

$$u_{i-1} = u_{i+1} - 2\Delta x u_x$$

RIGHT BOUNDARY B.C.

Central Difference:

$$\frac{\partial^2 u}{\partial x^2} = \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2}$$

Boundary Condition:

$$u_x = 0 \Rightarrow u_{i+1} = u_{i-1}$$

TOP BOUNDARY B.C.

Central Difference:

$$\frac{\partial^2 u}{\partial y^2} = \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta y^2}$$

Boundary Condition:

$$u_y = 0 \Rightarrow u_{i+1} = u_{i-1}$$

LEFT BOUNDARY B.C.

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$$\frac{\partial^2 u}{\partial x^2} = \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2}$$

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Central Difference:

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TOP BOUNDARY B.C.

Central Difference:

$$\frac{\partial^2 u}{\partial y^2} = \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta y^2}$$

Boundary Condition:

$$u_y = 0 \Rightarrow u_{i+1} = u_{i-1}$$

[A] MATRIX

Central Difference:

$$-u_{i-1} + 2u_i - u_{i+1} = -2\Delta x^2 u_{xx}$$

Boundary Conditions:

Left: $u_{i-1} = u_{i+1} - 2\Delta x u_x$

Right: $u_{i+1} = u_{i-1} + 2\Delta x u_x$

FINITE DIFFERENCE

Centered Finite-Difference Approximation:

$$f'(x) = \frac{f(x+\Delta x) - f(x-\Delta x)}{2\Delta x}$$

$$f''(x) = \frac{f(x+\Delta x) - 2f(x) + f(x-\Delta x))}{\Delta x^2}$$

Numerical Methods For Mathematics Science And Engineering

Richard Hamming



Numerical Methods For Mathematics Science And Engineering:

Numerical Methods for Mathematics, Science, and Engineering John H. Mathews,1992 A modern computer oriented approach to numerical analysis that shows how the mathematics of calculus and linear algebra are implemented in computer algorithms Computer output is displayed in tables and used to develop topics of computer accuracy pitfalls in computational methods and error estimation

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[Numerical Analysis for Science, Engineering and Technology](#) Said Gamil Ahmed,Hossein Jafari,Mukhtar Yagoub Youssif,Roberto Datja,2018-05-02 This textbook is intended as a guide for undergraduate and graduate students in engineering science and technology courses Chapters of the book cover the numerical concepts of errors approximations differential equations and partial differential equations The simple presentation of numerical concepts and illustrative examples helps students and general readers to understand the topics covered in the text

Numerical Methods in Engineering & Science Graham de Vahl Davis,1986-01-01 Very Good No Highlights or Markup all pages are intact

Numerical Methods for Scientists and Engineers Richard Hamming,2012-04-25 This inexpensive paperback edition of a groundbreaking text stresses frequency approach in coverage of algorithms polynomial approximation Fourier approximation exponential approximation and other topics Revised and enlarged 2nd edition

Numerical Methods Using MATLAB John H. Mathews,Kurtis D. Fink,2004 Balancing theory with practice this is an introductory text for undergraduates in mathematics science and engineering Illustrated throughout with graphs and tables the fourth edition contains many new features and each numerical method is presented in a self contained format

Numerical Methods in Engineering and Applied Science Bruce Irons,Nigel Shrive,1987

An Introduction to Numerical Methods and Analysis James F. Epperson,2021-07-21 The new edition of the popular introductory textbook on numerical approximation methods and mathematical analysis with a unique emphasis on real world application An Introduction to Numerical Methods and Analysis helps students gain a solid understanding of a wide range of numerical approximation methods for solving problems of

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An Introduction to Numerical Methods and Analysis Third Edition is the perfect textbook for upper level undergraduate students in mathematics science and engineering courses as well as for courses in the social sciences medicine and business with numerical methods and analysis components

Numerical Methods for Engineers and Scientists Joe D. Hoffman, Steven Frankel, 2018-10-03 Emphasizing the finite difference approach for solving differential equations the second edition of Numerical Methods for Engineers and Scientists presents a methodology for systematically constructing individual computer programs Providing easy access to accurate solutions to complex scientific and engineering problems each chapter begins with objectives a discussion of a representative application and an outline of special features summing up with a list of tasks students should be able to complete after reading the chapter perfect for use as a study guide or for review The AIAA Journal calls the book a good solid instructional text on the basic tools of numerical analysis

Numerical Methods for Computer Science, Engineering, and Mathematics John H. Mathews, 1987

Numerical Methods in Engineering Pramote Dechaumphai, N. Wansophark, 2011 NUMERICAL METHODS IN ENGINEERING Theories with MATLAB Fortran C and Pascal Programs presents a clear easy to understand manner on introduction and the use of numerical methods The book contains nine chapters with materials that are essential for studying the subject The book starts from introducing the numerical methods and describing their importance for analyzing engineering problems The methods for finding roots of linear and nonlinear equations are presented with examples Some of these methods are very effective and implemented in commercial software The methods for interpolation extrapolation and least squares regression are explained Numerical integration and differentiation methods are presented to demonstrate their

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Numerical Methods for Solving Partial Differential Equations George F. Pinder, 2017-12-06 A comprehensive guide to numerical methods for simulating physical chemical systems This book offers a systematic highly accessible presentation of numerical methods used to simulate the behavior of physical chemical systems Unlike most books on the subject it focuses on methodology rather than specific applications Written for students and professionals across an array of scientific and engineering disciplines and with varying levels of experience with applied mathematics it provides comprehensive descriptions of numerical methods without requiring an advanced mathematical background Based on its author s more than forty years of experience teaching numerical methods to engineering students *Numerical Methods for Solving Partial Differential Equations* presents the fundamentals of all of the commonly used numerical methods for solving differential equations at a level appropriate for advanced undergraduates and first year graduate students in science and engineering Throughout elementary examples show how numerical methods are used to solve generic versions of equations that arise in many scientific and engineering disciplines In writing it the author took pains to ensure that no assumptions were made about the background discipline of the reader Covers the spectrum of numerical methods that are used to simulate the behavior of physical chemical systems that occur in science and engineering Written by a professor of engineering with more than forty years of experience teaching numerical methods to engineers Requires only elementary knowledge of differential equations and matrix algebra to master the material Designed to teach students to understand appreciate and apply the basic mathematics and equations on which Mathcad and similar commercial software packages are based Comprehensive yet accessible to readers with limited mathematical knowledge *Numerical Methods for Solving Partial Differential Equations* is an excellent text for advanced undergraduates and first year graduate students in the sciences and engineering It is also a valuable working reference for professionals in engineering physics chemistry computer science and applied mathematics

[A First Course in Numerical Methods](#) Uri M. Ascher, Chen Greif, 2011-07-14 Offers students a practical knowledge of modern techniques in scientific computing

Integral Methods in Science and Engineering Mario Paul Ahues, Alain R. Largillier, 2011-06-28 An outgrowth of The Seventh International Conference on Integral Methods in Science and Engineering this book focuses on applications of integration based analytic and numerical techniques The contributors to the volume draw from a number of physical domains

and propose diverse treatments for various mathematical models through the use of integration as an essential solution tool. Physically meaningful problems in areas related to finite and boundary element techniques, conservation laws, hybrid approaches, ordinary and partial differential equations, and vortex methods are explored in a rigorous, accessible manner. The new results provided are a good starting point for future exploitation of the interdisciplinary potential of integration as a unifying methodology for the investigation of mathematical models.

Fundamentals of Engineering Numerical Analysis Parviz Moin, 2010-08-23. In this work Parviz Moin introduces numerical methods and shows how to develop, analyse, and use them. A thorough and practical text, it is intended as a first course in numerical analysis.

Numerical Methods for Engineers and Scientists Using MATLAB® Ramin S. Esfandiari, 2013-06-04. Designed to benefit scientific and engineering applications, *Numerical Methods for Engineers and Scientists Using MATLAB* focuses on the fundamentals of numerical methods while making use of MATLAB software. The book introduces MATLAB early on and incorporates it throughout the chapters to perform symbolic, graphical, and numerical tasks. The text covers a variety of methods from curve fitting to solving ordinary and partial differential equations. Provides fully worked out examples showing all details. Confirms results through the execution of the user-defined function or the script file. Executes built-in functions for re-confirmation when available. Generates plots regularly to shed light on the soundness and significance of the numerical results. Created to be user-friendly and easily understandable. *Numerical Methods for Engineers and Scientists Using MATLAB* provides background material and a broad introduction to the essentials of MATLAB, specifically its use with numerical methods. Building on this foundation, it introduces techniques for solving equations and focuses on curve fitting and interpolation techniques. It addresses numerical differentiation and integration methods, presents numerical methods for solving initial value and boundary value problems, and discusses the matrix eigenvalue problem, which entails numerical methods to approximate a few or all eigenvalues of a matrix. The book then deals with the numerical solution of partial differential equations, specifically those that frequently arise in engineering and science. The book presents a user-defined function or a MATLAB script file for each method, followed by at least one fully worked out example. When available, MATLAB built-in functions are executed for confirmation of the results. A large set of exercises of varying levels of difficulty appears at the end of each chapter. The concise approach with strong, up-to-date MATLAB integration provided by this book affords readers a thorough knowledge of the fundamentals of numerical methods utilized in various disciplines.

Numerical Methods for Engineers and Scientists J. N. Sharma (M.A.), 2004. The desire for numerical answers to applied problems has increased manifold with the advances made in various branches of science and engineering and rapid development of high-speed digital computers. Although numerical methods have always been useful, their role in the present-day scientific computations and research is of fundamental importance. Numerous distinguishing features: The contents of the book have been organized in a logical order and the topics are discussed in a systematic manner: concepts, algorithms, and numerous exercises at the end of each chapter.

helps students in problem solving both manually and through computer programming an exhaustive bibliography and an appendix containing some important and useful iterative methods for the solution of nonlinear complex equations

Numerical Methods in Engineering & Science Graham de Vahl Davis, 2012-03-01 This book is designed for an introductory course in numerical methods for students of engineering and science at universities and colleges of advanced education It is an outgrowth of a course of lectures and tutorials problem solving sessions which the author has given for a number of years at the University of New South Wales and elsewhere The course is normally taught at the rate of 11 hours per week throughout an academic year 28 weeks It has occasionally been given at double this rate over half the year but it was found that students had insufficient time to absorb the material and experiment with the methods The material presented here is rather more than has been taught in anyone year although all of it has been taught at some time The book is concerned with the application of numerical methods to the solution of equations algebraic transcendental and differential which will be encountered by students during their training and their careers The theoretical foundation for the methods is not rigorously covered Engineers and applied scientists but not of course mathematicians are more concerned with using methods than with proving that they can be used However they must be satisfied that the methods are fit to be used and it is hoped that students will perform sufficient numerical experiments to convince themselves of this without the need for more than the minimum of theory which is presented here

Variational Methods in Mathematics, Science and Engineering K. Rektorys, 1980-02-29 Hilbert space Variational methods Application of variational methods to the solution of boundary value problems in ordinary and partial differential equations Theory of boundary value problems in differential equations based on the concept of a weak solution and on the lax milgram theorem The eigenvalue problem Some special methods Regularity of the weak solution

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