

NUMERICAL METHODS

C / KAPPA EXAM 12 / 11/14 / 2022 / 20.00%

LEAST SQUARES REGRESSION

Goal: Minimize the sum of the squares of the residuals (errors).

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

Sum of Squares: $S_y = \sum_{i=1}^n (y_i - \hat{y}_i)^2 = \sum_{i=1}^n (y_i - a_0 - a_1 x_i)^2$

Normal Equations:

$$\begin{aligned} S_y &= \sum_{i=1}^n (y_i - a_0 - a_1 x_i)^2 \\ \frac{\partial S_y}{\partial a_0} &= -2 \sum_{i=1}^n (y_i - a_0 - a_1 x_i) = 0 \\ \frac{\partial S_y}{\partial a_1} &= -2 \sum_{i=1}^n x_i (y_i - a_0 - a_1 x_i) = 0 \end{aligned}$$

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 & STANDARD DEVIATION

Standard Error of the Estimate:

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

Standard Deviation:

$$S_y = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n-1}}$$

Example:

$$a_0 = \bar{y} - a_1 \bar{x}$$

INTERPOLATION

Use a polynomial $P(x)$ to approximate $f(x)$.

Degree	Points	Formula
Linear	2 points	$P_1(x) = a_0 + a_1 x$
Quadratic	3 points	$P_2(x) = a_0 + a_1 x + a_2 x^2$
Cubic	4 points	$P_3(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$
Quartic	5 points	$P_4(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4$

Splicing:

$$P(x) = \frac{f(x_1) - f(x_2)}{x_1 - x_2}$$

POLYNOMIAL QUADRATIC REGRESSION

Goal: Minimize the sum of the squares of the residuals for a quadratic fit.

$$S_y = \sum_{i=1}^n (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2$$

Normal Equations:

$$\begin{aligned} \frac{\partial S_y}{\partial a_0} &= -2 \sum_{i=1}^n (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0 \\ \frac{\partial S_y}{\partial a_1} &= -2 \sum_{i=1}^n x_i (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0 \\ \frac{\partial S_y}{\partial a_2} &= -2 \sum_{i=1}^n x_i^2 (y_i - a_0 - a_1 x_i - a_2 x_i^2) = 0 \end{aligned}$$

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:

$$y_{n+1} = y_n + f(x_n, y_n) \Delta x$$

Heun's Method:

$$y_{n+1} = y_n + \frac{f(x_n, y_n) + f(x_{n+1}, y_{n+1})}{2} \Delta x$$

Taylor Series & Classic 4th Order Runge-Kutta

Taylor Series:

$$y(x+\Delta x) = y(x) + \Delta x y'(x) + \frac{\Delta x^2}{2} y''(x) + \frac{\Delta x^3}{6} y'''(x) + \frac{\Delta x^4}{24} y^{(4)}(x)$$

Classic 4th Order Runge-Kutta:

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

where:

$$\begin{aligned} k_1 &= f(x_n, y_n) \\ k_2 &= f(x_n + \frac{\Delta x}{2}, y_n + \frac{\Delta x}{2} k_1) \\ k_3 &= f(x_n + \frac{\Delta x}{2}, y_n + \Delta x k_2) \\ k_4 &= f(x_n + \Delta x, y_n + \Delta x k_3) \end{aligned}$$

PDE'S

FINITE DIFFERENCE METHOD

Central Difference:

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

Forward Difference:

$$\frac{\partial u}{\partial x} \approx \frac{u_i - u_{i-1}}{\Delta x}$$

Backward Difference:

$$\frac{\partial u}{\partial x} \approx \frac{u_{i+1} - u_i}{\Delta x}$$

EIGEN VALUES

Example:

$$A = \begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix}$$

Characteristic Equation:

$$\det(A - \lambda I) = 0 \Rightarrow (1-\lambda)^2 - 4 = 0 \Rightarrow \lambda^2 - 2\lambda - 3 = 0 \Rightarrow \lambda = 3, -1$$

Single 2x2 Matrix

Example:

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

Eigenvalues:

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

2x2 Matrix with Eigenvalues

Example:

$$A = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

Eigenvalues: $\lambda_1 = 2, \lambda_2 = 0$

Eigenvectors:

$$v_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}, v_2 = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

[A] MATRIX

Central Difference:

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

Forward Difference:

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

Backward Difference:

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

HEAT CONDUCTION

Central Difference:

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

Forward Difference:

$$\frac{\partial u}{\partial x} \approx \frac{u_i - u_{i-1}}{\Delta x}$$

Backward Difference:

$$\frac{\partial u}{\partial x} \approx \frac{u_{i+1} - u_i}{\Delta x}$$

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HEAT CONDUCTION

Central Difference:

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$$\frac{\partial u}{\partial x} \approx \frac{u_i - u_{i-1}}{\Delta x}$$

Backward Difference:

$$\frac{\partial u}{\partial x} \approx \frac{u_{i+1} - u_i}{\Delta x}$$

Numerical Methods In Eng

**Petre Teodorescu, Nicolae-Doru
Stanescu, Nicolae Pandrea**



Numerical Methods In Eng:

Numerical Methods in Science and Engineering – A Practical Approach Rajasekaran S.,2003 During the past two decades owing to the advent of digital computers numerical methods of analysis have become very popular for the solution of complex problems in physical and management sciences and in engineering As the price of hardware keeps decreasing rapidly experts predict that in the near future one may have to pay only for software This underscores the importance of numerical computation to the scientist and engineers and today most undergraduates and postgraduates are being given training in the use of computers and access to the computers for the solution of problems

Numerical Methods For Scientific And Engineering Computation M.K. Jain,2003 Innovative Numerical Methods in Engineering R.P. Shaw,1986-04

Numerical Methods In Engineering & Science Carl .E. Pearson,1986-05-01 This book is designed for an introductory course in numerical methods for students of engineering and science at universities and colleges of advanced education

Numerical Methods For Engineers: A Practical Approach Abdulmajeed A Mohamad,Adel M Benselama,2022-07-27 The unique compendium is an introductory reference to learn the most popular numerical methods cohesively The text focuses on practical applications rather than on abstract and heavy analytical concepts The key elements of the numerical methods are Taylor series and linear algebra Based on the authors years of experience most materials on the text are tied to those elements in a unified manner The useful reference manual benefits professionals researchers academics senior undergraduate and graduate students in chemical engineering civil engineering mechanical engineering and aerospace engineering

Numerical Methods for Science and Engineering. -- Ralph G Stanton,2021-09-09 This work has been selected by scholars as being culturally important and is part of the knowledge base of civilization as we know it This work is in the public domain in the United States of America and possibly other nations Within the United States you may freely copy and distribute this work as no entity individual or corporate has a copyright on the body of the work Scholars believe and we concur that this work is important enough to be preserved reproduced and made generally available to the public To ensure a quality reading experience this work has been proofread and republished using a format that seamlessly blends the original graphical elements with text in an easy to read typeface We appreciate your support of the preservation process and thank you for being an important part of keeping this knowledge alive and relevant

Numerical Methods in Engineering Amiya K. Jana,2024-10-24 This textbook strikes a balance between theory and practice to introduce engineering students to numerical methods and their process applications

Numerical Analysis with Applications in Mechanics and Engineering Petre Teodorescu,Nicolae-Doru Stanescu,Nicolae Pandrea,2013-06-04 NUMERICAL ANALYSIS WITH APPLICATIONS IN MECHANICS AND ENGINEERING

A much needed guide on how to use numerical methods to solve practical engineering problems Bridging the gap between mathematics and engineering Numerical Analysis with Applications in Mechanics and Engineering arms readers with powerful tools for solving real world problems in mechanics

physics and civil and mechanical engineering Unlike most books on numerical analysis this outstanding work links theory and application explains the mathematics in simple engineering terms and clearly demonstrates how to use numerical methods to obtain solutions and interpret results Each chapter is devoted to a unique analytical methodology including a detailed theoretical presentation and emphasis on practical computation Ample numerical examples and applications round out the discussion illustrating how to work out specific problems of mechanics physics or engineering Readers will learn the core purpose of each technique develop hands on problem solving skills and get a complete picture of the studied phenomenon Coverage includes How to deal with errors in numerical analysis Approaches for solving problems in linear and nonlinear systems Methods of interpolation and approximation of functions Formulas and calculations for numerical differentiation and integration Integration of ordinary and partial differential equations Optimization methods and solutions for programming problems Numerical Analysis with Applications in Mechanics and Engineering is a one of a kind guide for engineers using mathematical models and methods as well as for physicists and mathematicians interested in engineering problems

Applied Numerical Methods for Engineers Terrence J. Akai, 1994 This book is also available through the Introductory Engineering Custom Publishing System If you are interested in creating a course pack that includes chapters from this book you can get further information by calling 212 850 6272 or sending email inquiries to engineerjwiley.com Designed to cover scores of numerical techniques including statistical methods encountered by engineers and technologists Pedagogically sound it uses a conversational style and contains highlighted key words and end of chapter summaries along with method summary pitfalls and recommendations for choice of techniques 80% of the worked examples and case studies are based on applied problems A complete chapter on design features problems relevant to using this tool in engineering practice Offers over 40 pseudocodes for implementing methods discussed Publisher *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 **Computational Methods in Engineering** S. P. Venkateshan, Prasanna Swaminathan, 2023-05-31 The book is designed to serve as a textbook for courses offered to graduate and upper undergraduate students enrolled in mechanical engineering The book attempts to make students with mathematical backgrounds comfortable with numerical methods The book also serves as a handy reference for practicing engineers who are interested in applications The book is written in an easy to understand manner with the essence of each numerical method clearly stated This makes it easy for professional engineers students and early career researchers to follow the material presented in the book The structure of the book has been modeled accordingly It is divided into four modules i solution of a system of equations and eigenvalues which includes linear equations determining eigenvalues and solution of nonlinear equations ii function approximations interpolation data fit numerical differentiation and

numerical integration iii solution of ordinary differential equations initial value problems and boundary value problems and iv solution of partial differential equations parabolic elliptic and hyperbolic PDEs Each section of the book includes exercises to reinforce the concepts and problems have been added at the end of each chapter Exercise problems may be solved by using computational tools such as scientific calculators spreadsheet programs and MATLAB codes The detailed coverage and pedagogical tools make this an ideal textbook for students early career researchers and professionals *Computational Engineering - Introduction to Numerical Methods* Michael Schäfer,2006-02-20 Introduction Modelling of Continuum Mechanical Problems Discretization of Problem Domain Finite Volume Methods Finite Element Methods Time Discretization Solution of Algebraic Systems of Equations Properties of Numerical Methods Finite Element Methods in Structural Mechanics Finite Volume Methods for Incompressible Flows Acceleration of Computations List of Symbols References Index

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 in Engineering & Science Graham de Vahl Davis,2012-12-06 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 **Numerical Methods for Nonlinear Engineering**

Models John R. Hauser,2009-03-24 There are many books on the use of numerical methods for solving engineering problems and for modeling of engineering artifacts In addition there are many styles of such presentations ranging from books with a major emphasis on theory to books with an emphasis on applications The purpose of this book is hopefully to present a somewhat different approach to the use of numerical methods for engineering applications Engineering models are in general nonlinear models where the response of some appropriate engineering variable depends in a nonlinear manner on the application of some independent parameter It is certainly true that for many types of engineering models it is sufficient to

approximate the real physical world by some linear model. However, when engineering environments are pushed to extreme conditions, nonlinear effects are always encountered. It is also such extreme conditions that are of major importance in determining the reliability or failure limits of engineering systems. Hence, it is essential that engineers have a toolbox of modeling techniques that can be used to model nonlinear engineering systems. Such a set of basic numerical methods is the topic of this book. For each subject area treated, nonlinear models are incorporated into the discussion from the very beginning, and linear models are simply treated as special cases of more general nonlinear models. This is a basic and fundamental difference in this book from most books on numerical methods. *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.

Discrete Numerical Methods in Physics and Engineering Greenspan, 1974-05-31. Discrete Numerical Methods in Physics and Engineering **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 reconfirmation 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 Engineering and Science* Saumyen Guha, Rajesh Srivastava (Civil engineer), 2010-12. Designed as a textbook for undergraduate and postgraduate students of engineering and science. *Numerical Methods For Engineering and Science* is an attempt to explain the concepts and principles in such a way that the

methods can be applied to any discipline **Numerical Methods in Biomedical Engineering** Stanley Dunn,Alkis Constantinides,Prabhas V. Moghe,2005-11-21 Numerical Modeling in Biomedical Engineering brings together the integrative set of computational problem solving tools important to biomedical engineers Through the use of comprehensive homework exercises relevant examples and extensive case studies this book integrates principles and techniques of numerical analysis Covering biomechanical phenomena and physiologic cell and molecular systems this is an essential tool for students and all those studying biomedical transport biomedical thermodynamics ABET oriented pedagogical layout Extensive hands on homework exercises

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