

NUMERICAL METHODS

C / KAPPA EXAM 12 / 11/19 / 2022 [20.00]

LEAST SQUARES REGRESSION

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

Residuals are the vertical distances between the data points and the fitted line.

$$S_r = \sum_{i=1}^n d_i = \sum_{i=1}^n (y_i - a_0 - a_1 x_i)$$

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

Minimize S_r^2 by setting $\frac{\partial S_r^2}{\partial a_0} = 0$ and $\frac{\partial S_r^2}{\partial a_1} = 0$.

$$a_0 = \frac{\sum y_i}{n} - a_1 \frac{\sum x_i}{n}$$

$$a_1 = \frac{\sum x_i y_i - \frac{(\sum x_i)(\sum y_i)}{n}}{\sum x_i^2 - \frac{(\sum x_i)^2}{n}}$$

STANDARD ERROR:

$$S_{y_1} = \sqrt{\frac{S_r}{n-2}}$$

$$S_{y_2} = \sqrt{\frac{S_r (1 - r^2)}{n-2}}$$

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{S_r}{n-1}}$$

$$S_x = \sqrt{\frac{\sum x_i^2 - \frac{(\sum x_i)^2}{n}}{n-1}}$$

INTERPOLATION

Use a 4th order polynomial

Order	Nodes	Degree	Nodes	Degree
1st	2	1	2	1
2nd	3	2	3	2
3rd	4	3	4	3
4th	5	4	5	4

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

Newton's form: $P_n(x) = f(x_0) + f[x_0, x_1](x-x_0) + f[x_0, x_1, x_2](x-x_0)(x-x_1) + \dots$

Divided differences table:

$f[x_0]$	$f[x_0, x_1]$	$f[x_0, x_1, x_2]$	$f[x_0, x_1, x_2, x_3]$
$f[x_1]$	$f[x_1, x_2]$	$f[x_1, x_2, x_3]$	
$f[x_2]$	$f[x_2, x_3]$		
$f[x_3]$			

POLYNOMIAL QUADRATIC REGRESSION

Goal: find the best fit quadratic curve to the data points.

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

Minimize S_r by setting $\frac{\partial S_r}{\partial a_0} = 0$, $\frac{\partial S_r}{\partial a_1} = 0$, and $\frac{\partial S_r}{\partial a_2} = 0$.

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

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

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

Matrix form: $[X^T X]^{-1} [X^T Y] = [a]$

ODE'S

Euler's Method

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

Runge-Kutta Method

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

Higher order Runge-Kutta methods:

- 2nd order: $y_{n+1} = y_n + \Delta x (k_1 + \frac{1}{2} k_2)$
- 3rd order: $y_{n+1} = y_n + \Delta x (\frac{1}{6} k_1 + \frac{4}{6} k_2 + \frac{1}{6} k_3)$
- 4th order: $y_{n+1} = y_n + \Delta x (\frac{1}{24} k_1 + \frac{16}{24} k_2 + \frac{5}{24} k_3 + \frac{1}{24} k_4)$

Taylor Series

$$y(x) = y_0 + y'_0(x-x_0) + \frac{y''_0}{2!}(x-x_0)^2 + \dots$$

Classic 4th order Runge-Kutta

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

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

PDE'S

Finite Difference Method

Discretize the domain into a grid. Approximate derivatives using finite differences.

Central Difference:

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

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

Boundary conditions: Dirichlet (fixed value), Neumann (fixed derivative).

EIGEN VALUES

Find eigenvalues λ and eigenvectors v for matrix A .

$$(A - \lambda I)v = 0$$

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

$$\det(A - \lambda I) = \det \begin{bmatrix} 1-\lambda & 2 \\ 2 & 1-\lambda \end{bmatrix} = (1-\lambda)^2 - 4 = 0$$

$$\lambda^2 - 2\lambda - 3 = 0 \Rightarrow \lambda = 3, -1$$

Single 2x2

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

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

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

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

3x3 Matrix

$$A = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}$$

$$\det(A - \lambda I) = 0$$

Example: $A = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

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

3x3 Matrix

$$A = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Eigenvectors for $\lambda = 1$:

$$(A - I)v = 0 \Rightarrow \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = 0$$

$v_2 = 0$, $v_1 = 0$, v_3 is free.

[A] MATRIX

Matrix for the finite difference method:

$$A_{i,j} = \begin{cases} -1 & j = i-1 \\ 2 & j = i \\ -1 & j = i+1 \end{cases}$$

Boundary conditions: $u_0 = 0$, $u_{N+1} = 0$.

RIGHT NEIGHBOR B.C.

$$\frac{\partial u}{\partial x} = 0 \Rightarrow u_{N+1} - u_N = 0$$

$$u_{N+1} = u_N$$

BOTTOM NEIGHBOR B.C.

$$\frac{\partial u}{\partial x} = 0 \Rightarrow u_{N+1} - u_N = 0$$

$$u_{N+1} = u_N$$

TOP NEIGHBOR B.C.

$$\frac{\partial u}{\partial x} = 0 \Rightarrow u_{N+1} - u_N = 0$$

$$u_{N+1} = u_N$$

LEFT NEIGHBOR B.C.

$$u_{N+1} = u_N - 2 \Delta x G_0$$

TRUNCATION ERROR

Centered finite-difference error term:

$$f(x) = \frac{f(x_0) - f(x_0 - \Delta x)}{2 \Delta x}$$

$$f(x) = \frac{f(x_0) - [f(x_0) - \Delta x f'(x_0) + \frac{(\Delta x)^2}{2} f''(x_0) - \dots]}{2 \Delta x}$$

Numerical Methods For Mathematics Science And Engineering

Pramote Dechaumphai, N. Wansophark

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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 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

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of mathematical analysis Designed for entry level courses on the subject this popular textbook maximizes teaching flexibility by first covering basic topics before gradually moving to more advanced material in each chapter and section Throughout the text students are provided clear and accessible guidance on a wide range of numerical methods and analysis techniques including root finding numerical integration interpolation solution of systems of equations and many others This fully revised third edition contains new sections on higher order difference methods the bisection and inertia method for computing eigenvalues of a symmetric matrix a completely re written section on different methods for Poisson equations and spectral methods for higher dimensional problems New problem sets ranging in difficulty from simple computations to challenging derivations and proofs are complemented by computer programming exercises illustrative examples and sample code This acclaimed textbook Explains how to both construct and evaluate approximations for accuracy and performance Covers both elementary concepts and tools and higher level methods and solutions Features new and updated material reflecting new trends and applications in the field Contains an introduction to key concepts a calculus review an updated primer on computer arithmetic a brief history of scientific computing a survey of computer languages and software and a revised literature review Includes an appendix of proofs of selected theorems and a companion website with additional exercises application models and supplemental resources

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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.

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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 1½ 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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Table of Contents Numerical Methods For Mathematics Science And Engineering

1. Understanding the eBook Numerical Methods For Mathematics Science And Engineering
 - The Rise of Digital Reading Numerical Methods For Mathematics Science And Engineering
 - Advantages of eBooks Over Traditional Books
2. Identifying Numerical Methods For Mathematics Science And Engineering
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Numerical Methods For Mathematics Science And Engineering
 - User-Friendly Interface

4. Exploring eBook Recommendations from Numerical Methods For Mathematics Science And Engineering
 - Personalized Recommendations
 - Numerical Methods For Mathematics Science And Engineering User Reviews and Ratings
 - Numerical Methods For Mathematics Science And Engineering and Bestseller Lists
5. Accessing Numerical Methods For Mathematics Science And Engineering Free and Paid eBooks
 - Numerical Methods For Mathematics Science And Engineering Public Domain eBooks
 - Numerical Methods For Mathematics Science And Engineering eBook Subscription Services
 - Numerical Methods For Mathematics Science And Engineering Budget-Friendly Options
6. Navigating Numerical Methods For Mathematics Science And Engineering eBook Formats
 - ePub, PDF, MOBI, and More
 - Numerical Methods For Mathematics Science And Engineering Compatibility with Devices
 - Numerical Methods For Mathematics Science And Engineering Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Numerical Methods For Mathematics Science And Engineering
 - Highlighting and Note-Taking Numerical Methods For Mathematics Science And Engineering
 - Interactive Elements Numerical Methods For Mathematics Science And Engineering
8. Staying Engaged with Numerical Methods For Mathematics Science And Engineering
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Numerical Methods For Mathematics Science And Engineering
9. Balancing eBooks and Physical Books Numerical Methods For Mathematics Science And Engineering
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Numerical Methods For Mathematics Science And Engineering
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Numerical Methods For Mathematics Science And Engineering
 - Setting Reading Goals Numerical Methods For Mathematics Science And Engineering
 - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Numerical Methods For Mathematics Science And Engineering
 - Fact-Checking eBook Content of Numerical Methods For Mathematics Science And Engineering
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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