

NUMERICAL METHODS

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

LEAST SQUARES REGRESSION

Goal: minimize the sum of the square of the residual (error).

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

Sum of squares = $\sum (y_i - \hat{y}_i)^2$

Minimize: $\sum (y_i - \hat{y}_i)^2$

Model: $\hat{y} = a_0 + a_1 x$

Polynomial Quadratic Regression:

Model: $\hat{y} = a_0 + a_1 x + a_2 x^2$

Goal: minimize the sum of the square of the residual (error).

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STANDARD ERROR:

$$S_y = \sqrt{\frac{\sum y_i^2}{n-2}} \quad S_x = \sqrt{\frac{\sum x_i^2 - y^2}{n-2}}$$

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{\sum y_i^2}{n-1}} \quad S_x = \sqrt{\frac{\sum x_i^2 - y^2}{n-1}}$$

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

$$y = a_0 + a_1 x$$

INTERPOLATION

Use a polynomial fit:

Linear: $y = a_0 + a_1 x$

Quadratic: $y = a_0 + a_1 x + a_2 x^2$

Cubic: $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3$

Order: $n = 1, 2, 3, 4, \dots$

Turns: $n = 1, 2, 3, 4, \dots$

Spines: $n = 1, 2, 3, 4, \dots$

ODE's

Runge-Kutta Method

Heun's Method

Classic 4th order Runge-Kutta

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EIGEN VALUES

Example: $A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

Characteristic equation: $\det(A - \lambda I) = 0$

Eigen values: $\lambda_1 = 5, \lambda_2 = -1$

Eigen vectors: $\vec{v}_1 = \begin{bmatrix} 1 \\ 2 \end{bmatrix}, \vec{v}_2 = \begin{bmatrix} -2 \\ 1 \end{bmatrix}$

Diagonalization: $A = P \Lambda P^{-1}$

Power method: $\vec{x}_{k+1} = \frac{A \vec{x}_k}{\|A \vec{x}_k\|}$

QR method: $A = Q R$

Householder's method: $A = Q R$

Jacobi's method: $A = Q R$

Givens' method: $A = Q R$

LU decomposition: $A = L U$

Singular value decomposition: $A = U \Sigma V^T$

Principal component analysis: $A = U \Sigma V^T$

Least squares: $A \vec{x} = \vec{b}$

Linear regression: $A \vec{x} = \vec{b}$

Nonlinear regression: $A \vec{x} = \vec{b}$

Bayesian inference: $A \vec{x} = \vec{b}$

Machine learning: $A \vec{x} = \vec{b}$

Deep learning: $A \vec{x} = \vec{b}$

Reinforcement learning: $A \vec{x} = \vec{b}$

Game theory: $A \vec{x} = \vec{b}$

PDE'S

FINITE DIFFERENCE METHOD

Grid: x, y, z

Central difference: $\frac{\partial^2 u}{\partial x^2} = \frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{\Delta x^2}$

Forward difference: $\frac{\partial u}{\partial x} = \frac{u_{i+1,j} - u_{i,j}}{\Delta x}$

Backward difference: $\frac{\partial u}{\partial x} = \frac{u_{i,j} - u_{i-1,j}}{\Delta x}$

Central difference: $\frac{\partial^2 u}{\partial y^2} = \frac{u_{i,j+1} - 2u_{i,j} + u_{i,j-1}}{\Delta y^2}$

Forward difference: $\frac{\partial u}{\partial y} = \frac{u_{i,j+1} - u_{i,j}}{\Delta y}$

Backward difference: $\frac{\partial u}{\partial y} = \frac{u_{i,j} - u_{i,j-1}}{\Delta y}$

Central difference: $\frac{\partial^2 u}{\partial z^2} = \frac{u_{i,j,k+1} - 2u_{i,j,k} + u_{i,j,k-1}}{\Delta z^2}$

Forward difference: $\frac{\partial u}{\partial z} = \frac{u_{i,j,k+1} - u_{i,j,k}}{\Delta z}$

Backward difference: $\frac{\partial u}{\partial z} = \frac{u_{i,j,k} - u_{i,j,k-1}}{\Delta z}$

Central difference: $\frac{\partial^2 u}{\partial x \partial y} = \frac{u_{i+1,j+1} - u_{i+1,j} - u_{i,j+1} + u_{i,j}}{\Delta x \Delta y}$

Forward difference: $\frac{\partial^2 u}{\partial x \partial y} = \frac{u_{i+1,j+1} - u_{i+1,j} - u_{i,j+1} + u_{i,j}}{\Delta x \Delta y}$

Backward difference: $\frac{\partial^2 u}{\partial x \partial y} = \frac{u_{i+1,j+1} - u_{i+1,j} - u_{i,j+1} + u_{i,j}}{\Delta x \Delta y}$

Central difference: $\frac{\partial^2 u}{\partial x \partial y} = \frac{u_{i+1,j+1} - u_{i+1,j} - u_{i,j+1} + u_{i,j}}{\Delta x \Delta y}$

Forward difference: $\frac{\partial^2 u}{\partial x \partial y} = \frac{u_{i+1,j+1} - u_{i+1,j} - u_{i,j+1} + u_{i,j}}{\Delta x \Delta y}$

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Backward difference: $\frac{\partial^2 u}{\partial x \partial y} = \frac{u_{i+1,j+1} - u_{i+1,j} - u_{i,j+1} + u_{i,j}}{\Delta x \Delta y}$

HEAT CONDUCTION

1D: $\frac{\partial^2 T}{\partial x^2} = 0$

2D: $\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0$

3D: $\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = 0$

Steady state: $\frac{\partial T}{\partial t} = 0$

Transient: $\frac{\partial T}{\partial t} \neq 0$

Boundary conditions: $T = T_w$

Initial conditions: $T = T_0$

Heat flux: $q = -k \frac{\partial T}{\partial x}$

Heat generation: $\dot{q}''' = 0$

Heat sink: $\dot{q}''' = 0$

Heat source: $\dot{q}''' = 0$

Heat sink: $\dot{q}''' = 0$

Heat source: $\dot{q}''' = 0$

Heat sink: $\dot{q}''' = 0$

CONCENTRATED FINITE-DIFFERENCE METHOD

1D: $\frac{\partial^2 T}{\partial x^2} = 0$

2D: $\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0$

3D: $\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = 0$

Steady state: $\frac{\partial T}{\partial t} = 0$

Transient: $\frac{\partial T}{\partial t} \neq 0$

Boundary conditions: $T = T_w$

Initial conditions: $T = T_0$

Heat flux: $q = -k \frac{\partial T}{\partial x}$

Heat generation: $\dot{q}''' = 0$

Heat sink: $\dot{q}''' = 0$

Heat source: $\dot{q}''' = 0$

Heat sink: $\dot{q}''' = 0$

Heat source: $\dot{q}''' = 0$

Heat sink: $\dot{q}''' = 0$

5th ROW OF A MATRIX

Row 5: $[0 \ 1 \ 0 \ 1 \ 9 \ -1 \ 0 \ -1 \ 0]$

Row 6: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 7: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 8: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 9: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 10: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 11: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 12: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 13: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 14: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 15: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 16: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 17: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 18: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 19: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 20: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 21: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 22: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 23: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 24: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 25: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 26: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 27: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 28: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 29: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 30: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 31: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 32: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 33: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 34: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 35: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 36: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 37: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 38: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 39: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 40: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 41: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 42: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 43: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 44: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 45: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 46: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Row 47: $[0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0]$

Numerical Methods And Analysis

James F. Epperson



Numerical Methods And Analysis:

Analysis of Numerical Methods Eugene Isaacson, Herbert Bishop Keller, 2012-04-26 This excellent text for advanced undergraduate and graduate students covers norms numerical solutions of linear systems and matrix factoring eigenvalues and eigenvectors polynomial approximation and more Many examples and problems 1966 edition *Numerical Methods and Analysis* James L. Buchanan, Peter R. Turner, 1992 Intended for a first course in numerical methods or numerical analysis taken by junior and senior level students this book assumes a knowledge of calculus linear algebra and differential equations It covers numerical approximation interpolation graphics and parallel computing The interplay between hardware and software considerations in numerical algorithm design recurs throughout A portion of the programs in the book are written in Turbo Pascal the remainder are pseudocode or generalized algorithms Programs used in the text will be available on a disk for instructors to use and copy *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 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 *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 in Software and Analysis* John R. Rice, 2014-05-19 *Numerical Methods Software and Analysis Second Edition* introduces science and engineering

students to the methods tools and ideas of numerical computation Introductory courses in numerical methods face a fundamental problem there is too little time to learn too much This text solves that problem by using high quality mathematical software In fact the objective of the text is to present scientific problem solving using standard mathematical software This book discusses numerous programs and software packages focusing on the IMSL library including the PROTRAN system and ACM Algorithms The book is organized into three parts Part I presents the background material Part II presents the principal methods and ideas of numerical computation Part III contains material about software engineering and performance evaluation A uniform approach is used in each area of numerical computation First an intuitive development is made of the problems and the basic methods for their solution Then relevant mathematical software is reviewed and its use outlined Many areas provide extensive examples and case studies Finally a deeper analysis of the methods is presented as in traditional numerical analysis texts Emphasizes the use of high quality mathematical software for numerical computation

Extensive use of IMSL routines Features extensive examples and case studies **Theory and Applications of Numerical Analysis** G. M. Phillips, Peter J. Taylor, 1996-07-05 Theory and Applications of Numerical Analysis is a self contained Second Edition providing an introductory account of the main topics in numerical analysis The book emphasizes both the theorems which show the underlying rigorous mathematics and the algorithms which define precisely how to program the numerical methods Both theoretical and practical examples are included a unique blend of theory and applications two brand new chapters on eigenvalues and splines inclusion of formal algorithms numerous fully worked examples a large number of problems many with solutions Numerical Methods and Analysis of Multiscale Problems Alexandre L.

Madureira, 2017-02-15 This book is about numerical modeling of multiscale problems and introduces several asymptotic analysis and numerical techniques which are necessary for a proper approximation of equations that depend on different physical scales Aimed at advanced undergraduate and graduate students in mathematics engineering and physics or researchers seeking a no nonsense approach it discusses examples in their simplest possible settings removing mathematical hurdles that might hinder a clear understanding of the methods The problems considered are given by singular perturbed reaction advection diffusion equations in one and two dimensional domains partial differential equations in domains with rough boundaries and equations with oscillatory coefficients This work shows how asymptotic analysis can be used to develop and analyze models and numerical methods that are robust and work well for a wide range of parameters

Introduction to Numerical Analysis Devi Prasad, 2003 An Introduction to Numerical Analysis is designed for a first course on numerical analysis for students of Science and Engineering including Computer Science The book contains derivation of algorithms for solving engineering and science problems and also deals with error analysis It has numerical examples suitable for solving through computers The special features are comparative efficiency and accuracy of various algorithms due to finite digit arithmetic used by the computers **Numerical Analysis** M. Schatzman, 2002 Numerical

analysis explains why numerical computations work or fail This book is divided into four parts Part I starts with a guided tour of floating number systems and machine arithmetic The exponential and the logarithm are constructed from scratch to present a new point of view on questions well known to the reader and the needed knowledge of linear algebra is summarized Part II starts with polynomial approximation polynomial interpolation mean square approximation splines It then deals with Fourier series providing the trigonometric version of least square approximations and one of the most important numerical algorithms the fast Fourier transform Any scientific computation program spends most of its time solving linear systems or approximating the solution of linear systems even when trying to solve non linear systems Part III is therefore about numerical linear algebra while Part IV treats a selection of non linear or complex problems resolution of linear equations and systems ordinary differential equations single step and multi step schemes and an introduction to partial differential equations The book has been written having in mind the advanced undergraduate students in mathematics who are interested in the spice and spirit of numerical analysis The book does not assume previous knowledge of numerical methods It will also be useful to scientists and engineers wishing to learn what mathematics has to say about the reason why their numerical methods work or fail

Numerical Methods for Ordinary Differential Equations J. C. Butcher, 2008-04-15 In recent years the study of numerical methods for solving ordinary differential equations has seen many new developments This second edition of the author's pioneering text is fully revised and updated to acknowledge many of these developments It includes a complete treatment of linear multistep methods whilst maintaining its unique and comprehensive emphasis on Runge Kutta methods and general linear methods Although the specialist topics are taken to an advanced level the entry point to the volume as a whole is not especially demanding Early chapters provide a wide ranging introduction to differential equations and difference equations together with a survey of numerical differential equation methods based on the fundamental Euler method with more sophisticated methods presented as generalizations of Euler Features of the book include Introductory work on differential and difference equations A comprehensive introduction to the theory and practice of solving ordinary differential equations numerically A detailed analysis of Runge Kutta methods and of linear multistep methods A complete study of general linear methods from both theoretical and practical points of view The latest results on practical general linear methods and their implementation A balance between informal discussion and rigorous mathematical style Examples and exercises integrated into each chapter enhancing the suitability of the book as a course text or a self study treatise Written in a lucid style by one of the worlds leading authorities on numerical methods for ordinary differential equations and drawing upon his vast experience this new edition provides an accessible and self contained introduction ideal for researchers and students following courses on numerical methods engineering and other sciences

Numerical Analysis or Numerical Method in Symmetry Clemente Cesarano, 2020-02-21 This Special Issue focuses mainly on techniques and the relative formalism typical of numerical methods and therefore of numerical analysis more generally These fields of study of

mathematics represent an important field of investigation both in the field of applied mathematics and even more exquisitely in the pure research of the theory of approximation and the study of polynomial relations as well as in the analysis of the solutions of the differential equations both ordinary and partial derivatives Therefore a substantial part of research on the topic of numerical analysis cannot exclude the fundamental role played by approximation theory and some of the tools used to develop this research In this Special Issue we want to draw attention to the mathematical methods used in numerical analysis such as special functions orthogonal polynomials and their theoretical tools such as Lie algebra to study the concepts and properties of some special and advanced methods which are useful in the description of solutions of linear and nonlinear differential equations A further field of investigation is dedicated to the theory and related properties of fractional calculus with its adequate application to numerical methods

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Table of Contents Numerical Methods And Analysis

1. Understanding the eBook Numerical Methods And Analysis
 - The Rise of Digital Reading Numerical Methods And Analysis
 - Advantages of eBooks Over Traditional Books
2. Identifying Numerical Methods And Analysis
 - 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 And Analysis
 - User-Friendly Interface
4. Exploring eBook Recommendations from Numerical Methods And Analysis
 - Personalized Recommendations

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

- 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

Numerical Methods And Analysis Introduction

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