

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).

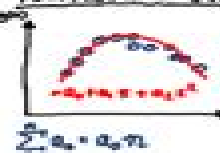
Residual = $y_i - \hat{y}_i$

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

Normal Equations:

$$\begin{aligned} a_0 &= \frac{\sum y_i}{n} \\ a_1 &= \frac{\sum x_i y_i}{\sum x_i^2} \end{aligned}$$

POLYNOMIAL QUADRATIC REGRESSION



$$\begin{aligned} S_0 &= \sum (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2 \\ \frac{\partial S_0}{\partial a_0} &= -2 \left(\sum y_i - \sum a_0 - a_1 \sum x_i - a_2 \sum x_i^2 \right) = 0 \\ \frac{\partial S_0}{\partial a_1} &= -2 \left(\sum x_i y_i - \sum a_0 \sum x_i - a_1 \sum x_i^2 - a_2 \sum x_i^3 \right) = 0 \\ \frac{\partial S_0}{\partial a_2} &= -2 \left(\sum x_i^2 y_i - \sum a_0 \sum x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4 \right) = 0 \end{aligned}$$

$$\begin{bmatrix} \sum 1 & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \\ \sum x_i^2 y_i \end{bmatrix}$$

STANDARD ERROR

$$S_y = \sqrt{\frac{\sum y_i^2}{n-2}} \quad S_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-2}}$$

STANDARD DEVIATION

$$S_y = \sqrt{\frac{\sum y_i^2}{n-1}} \quad S_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

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

$$y = a_0 + a_1 x$$

INTERPOLATION

Use a polynomial fit.

Linear: 2 points

Quadratic: 3 points

Cubic: 4 points

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

Order: $n=1$ (Linear), $n=2$ (Quadratic), $n=3$ (Cubic), $n=4$ (Quartic), $n=5$ (Quintic)

Turns: $n=1$ (0), $n=2$ (1), $n=3$ (2), $n=4$ (3), $n=5$ (4)

DEGREE 1

Linear

Quadratic

Cubic

DEGREE 2

Linear

Quadratic

Cubic

Polynomial

Order

Turns

Spines

Order

Turns

Spines

Order

Turns

Spines

Order

Turns

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ODE'S

Euler's Method

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

Runge-Kutta

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

Heun's Method

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

Adams-Bashforth

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

Adams-Moulton

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

Runge-Kutta

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Runge-Kutta

Taylor Series

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

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CLASSIC 4TH ORDER RUNGE-KUTTA

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

$$k_1 = f(x_n, y_n)$$

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

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

$$k_4 = f(x_n + \Delta x, y_n + \Delta x k_3)$$

Forward Euler

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

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PDE'S

FINITE DIFFERENCE METHOD



Central Difference

Forward Difference

Backward Difference

Central Difference

Forward Difference

Backward Difference

Central Difference

Forward Difference

Backward Difference

Central Difference

Forward Difference

Backward Difference

Central Difference

Forward Difference

Backward Difference

EIGEN VALUES

λ = Eigen Value

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

$$A - \lambda I = \begin{bmatrix} 1-\lambda & 2 \\ 3 & 4-\lambda \end{bmatrix}$$

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

$$(1-\lambda)(4-\lambda) - 6 = 0$$

$$\lambda^2 - 5\lambda + 10 = 0$$

$$\lambda = \frac{5 \pm \sqrt{25 - 40}}{2}$$

$$\lambda = \frac{5 \pm \sqrt{-15}}{2}$$

$$\lambda = \frac{5 \pm i\sqrt{15}}{2}$$

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Numerical Methods And Analysis

Eugene Isaacson, Herbert Bishop Keller



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 [An Introduction to Numerical Methods and Analysis](#) James F. Epperson, 2013-12-24 Praise for the First Edition outstandingly appealing with regard to its style contents considerations of requirements of practice choice of examples and exercises Zentralblatt MATH carefully structured with many detailed worked examples The Mathematical Gazette The Second Edition of the highly regarded An Introduction to Numerical Methods and Analysis provides a fully revised guide to numerical approximation The book continues to be accessible and expertly guides readers through the many available techniques of numerical methods and analysis An Introduction to Numerical Methods and Analysis Second Edition reflects the latest trends in the field includes new material and revised exercises and offers a unique emphasis on applications The author clearly explains how to both construct and evaluate approximations for accuracy and performance which are key skills in a variety of fields A wide range of higher level methods and solutions including new topics such as the roots of polynomials spectral collocation finite element ideas and Clenshaw Curtis quadrature are presented from an introductory perspective and the Second Edition also features Chapters and sections that begin with basic elementary material followed by gradual coverage of more advanced material Exercises ranging from simple hand computations to challenging derivations and minor proofs to programming exercises Widespread exposure and utilization of MATLAB An appendix that contains proofs of various theorems and other material The book is an ideal textbook for students in advanced undergraduate mathematics and engineering courses who are interested in gaining an understanding of numerical methods and numerical analysis **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 *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

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

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

Solutions Manual to accompany An Introduction to Numerical Methods and Analysis James F. Epperson, 2013-10-21 A solutions manual to accompany An Introduction to Numerical Methods and Analysis Second Edition An Introduction to Numerical Methods and Analysis Second Edition reflects the latest trends in the field includes new material and revised exercises and offers a unique emphasis on applications The author clearly explains how to both construct and evaluate approximations for accuracy and performance which are key skills in a variety of fields A wide range of higher level methods and solutions including new topics such as the roots of polynomials spectral collocation finite element ideas and Clenshaw Curtis quadrature are presented from an introductory perspective and

the Second Edition also features Chapters and sections that begin with basic elementary material followed by gradual coverage of more advanced material Exercises ranging from simple hand computations to challenging derivations and minor proofs to programming exercises Widespread exposure and utilization of MATLAB An appendix that contains proofs of various theorems and other material *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

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 *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 Applied Numerical Analysis Curtis F. Gerald, Patrick O. Wheatley, 1994 The fifth edition of this classic book continues its excellence in teaching numerical analysis and techniques

Interesting and timely applications motivate an understanding of methods and analysis of results Suitable for students with mathematics and engineering backgrounds the breadth of topics partial differential equations systems of nonlinear equations and matrix algebra provide comprehensive and flexible coverage of all aspects of all numerical analysis New sections discuss the use of computer algebra systems such as Mathematica Maple and DERIVE facilitate the integration of technology in the course

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

An Introduction to Numerical Analysis, 2nd Ed Kendall E. Atkinson, 2008-09 Market_Desc Mathematics Students Instructors About The Book This Second Edition of a standard numerical analysis text retains organization of the original edition but all sections have been revised some extensively and bibliographies have been updated New topics covered include optimization trigonometric interpolation and the fast Fourier transform numerical differentiation the method of lines boundary value problems the conjugate gradient method and the least squares solutions of systems of linear equations

Numerical Methods in Economics Kenneth L. Judd, 1998-09-28 To harness the full power of computer technology economists need to use a broad range of mathematical techniques In this book Kenneth Judd presents techniques from the numerical analysis and applied mathematics literatures and shows how to use them in economic analyses The book is divided into five parts Part I provides a general introduction Part II presents basics from numerical analysis on \mathbb{R}^n including linear equations iterative methods optimization nonlinear equations approximation methods numerical integration and differentiation and Monte Carlo methods Part III covers

methods for dynamic problems including finite difference methods projection methods and numerical dynamic programming Part IV covers perturbation and asymptotic solution methods Finally Part V covers applications to dynamic equilibrium analysis including solution methods for perfect foresight models and rational expectation models A website contains supplementary material including programs and answers to exercises [Numerical Analysis or Numerical Method in Symmetry](#) Clemente Cesarano,2020 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

Numerical Analysis for Engineers Bilal Ayyub,Richard H. McCuen,2015-09-18

Numerical Analysis for Engineers Methods and Applications demonstrates the power of numerical methods in the context of solving complex engineering and scientific problems The book helps to prepare future engineers and assists practicing engineers in understanding the fundamentals of numerical methods especially their applications limitations

Numerical Methods for Ordinary Differential Equations John Charles Butcher,2016 [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

Numerical Methods Anne Greenbaum, Tim P. Chartier, 2012-04-01 A rigorous and comprehensive introduction to numerical analysis Numerical Methods provides a clear and concise exploration of standard numerical analysis topics as well as nontraditional ones including mathematical modeling Monte Carlo methods Markov chains and fractals Filled with appealing examples that will motivate students the textbook considers modern application areas such as information retrieval and animation and classical topics from physics and engineering Exercises use MATLAB and promote understanding of computational results The book gives instructors the flexibility to emphasize different aspects design analysis or computer implementation of numerical algorithms depending on the background and interests of students Designed for upper division undergraduates in mathematics or computer science classes the textbook assumes that students have prior knowledge of linear algebra and calculus although these topics are reviewed in the text Short discussions of the history of numerical methods are interspersed throughout the chapters The book also includes polynomial interpolation at Chebyshev points use of the MATLAB package Chebfun and a section on the fast Fourier transform Supplementary materials are available online Clear and concise exposition of standard numerical analysis topics Explores nontraditional topics such as mathematical modeling and Monte Carlo methods Covers modern applications including information retrieval and animation and classical applications from physics and engineering Promotes understanding of computational results through MATLAB exercises Provides flexibility so instructors can emphasize mathematical or applied computational aspects of numerical methods or a combination Includes recent results on polynomial interpolation at Chebyshev points and use of the MATLAB package Chebfun Short discussions of the history of numerical methods interspersed throughout Supplementary materials available online [Introduction to Precise Numerical Methods](#) Oliver Aberth, 2007-04-11 Precise numerical analysis may be defined as the study of computer methods for solving mathematical problems either exactly or to prescribed accuracy This book explains how precise numerical analysis is constructed The book also provides exercises which illustrate points from the text and references for the methods presented Clearer simpler descriptions and explanations of the various numerical methods Two new types of numerical problems accurately solving partial differential equations with the included software and computing line integrals in the complex plane

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Numerical Methods And Analysis Introduction

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