

# NUMERICAL METHODS

C / KAPPA EXAM 12 / 11/14 / 1002 / 20, 20M

### LEAST SQUARES REGRESSION

Goal: minimize the sum of the squares of the residual (errors)

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

Sum of Squares Error (SSE):  $S_e = \sum_{i=1}^n (y_i - \hat{y}_i)^2$

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

Normal Equations:

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

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:

$$S_e = \sqrt{\frac{S_e}{n-2}}$$

Standard Deviation:

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

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

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

### INTERPOLATION

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

Degrees:

- Linear: 2 pts, 1 unknown
- Quadratic: 3 pts, 2 unknowns
- Cubic: 4 pts, 3 unknowns
- Quartic: 5 pts, 4 unknowns

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

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

Turns:  $n=1: 0, n=2: 1, n=3: 2, n=4: 3, \dots$

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

### POLYNOMIAL QUADRATIC REGRESSION

Goal: minimize the sum of the squares of the residual (errors)

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

Sum of Squares Error (SSE):  $S_e = \sum_{i=1}^n (y_i - \hat{y}_i)^2$

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

Normal Equations:

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

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

Euler's Method:

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

Runge-Kutta Method:

$$y_{i+1} = y_i + \frac{\Delta x}{6} (k_1 + 2k_2 + 2k_3 + k_4)$$

Classic 4th order Runge-Kutta:

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

### Taylor Series

Classic 4th order Runge-Kutta:

$$y_{i+1} = y_i + \frac{\Delta x}{6} (k_1 + 2k_2 + 2k_3 + k_4)$$

Runge-Kutta Method:

$$y_{i+1} = y_i + \frac{\Delta x}{6} (k_1 + 2k_2 + 2k_3 + k_4)$$

### 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:

$$\begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Characteristic Equation:

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

Eigenvalues:  $\lambda_1 = 3, \lambda_2 = -1$

### Single 2x2

Example:

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

Eigenvalues:  $\lambda_1 = 3, \lambda_2 = -1$

### Finite Difference Method

Example:

$$\begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Eigenvalues:  $\lambda_1 = 3, \lambda_2 = -1$

### Finite Difference Method

Example:

$$\begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Eigenvalues:  $\lambda_1 = 3, \lambda_2 = -1$

### [A] MATRIX

Example:

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

Eigenvalues:  $\lambda_1 = 3, \lambda_2 = -1$

### FINITE DIFFERENCE

Example:

$$\begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

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Eigenvalues:  $\lambda_1 = 3, \lambda_2 = -1$

# Methods In Numerical Analysis

**A. Cohen**



## **Methods In Numerical Analysis:**

**An Introduction to Numerical Methods and Analysis** James F. Epperson, 2007-09-17 Praise for the First Edition  
outstandingly appealing with regard to its style contents considerations of requirements of practice choice of examples and exercises Zentrablatt Math carefully structured with many detailed worked examples The Mathematical Gazette an up to date and user friendly account Mathematika An Introduction to Numerical Methods and Analysis addresses the mathematics underlying approximation and scientific computing and successfully explains where approximation methods come from why they sometimes work or don't work and when to use one of the many techniques that are available Written in a style that emphasizes readability and usefulness for the numerical methods novice the book begins with basic elementary material and gradually builds up to more advanced topics A selection of concepts required for the study of computational mathematics is introduced and simple approximations using Taylor's Theorem are also treated in some depth The text includes exercises that run the gamut from simple hand computations to challenging derivations and minor proofs to programming exercises A greater emphasis on applied exercises as well as the cause and effect associated with numerical mathematics is featured throughout the book An Introduction to Numerical Methods and Analysis is the ideal text for students in advanced undergraduate mathematics and engineering courses who are interested in gaining an understanding of numerical methods and numerical analysis

**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

**INTRODUCTORY METHODS OF NUMERICAL ANALYSIS, FIFTH EDITION** SASTRY, S. S., 2012-06-12 This thoroughly revised and updated text now in its fifth edition continues to provide a rigorous introduction to the fundamentals of numerical methods required in scientific and technological applications emphasizing on teaching students numerical methods and in helping them to develop problem solving skills While the essential features of the previous editions such as References to MATLAB IMSL Numerical Recipes program libraries for implementing the numerical methods are retained a chapter on Spline Functions has been added in this edition because of their increasing importance in applications This text is designed for undergraduate students of all branches of engineering **NEW TO THIS EDITION** Includes

additional modified illustrative examples and problems in every chapter Provides answers to all chapter end exercises Illustrates algorithms computational steps or flow charts for many numerical methods Contains four model question papers at the end of the text     Computational Methods for Numerical Analysis with R James P Howard, II, 2017-07-12

Computational Methods for Numerical Analysis with R is an overview of traditional numerical analysis topics presented using R This guide shows how common functions from linear algebra interpolation numerical integration optimization and differential equations can be implemented in pure R code Every algorithm described is given with a complete function implementation in R along with examples to demonstrate the function and its use Computational Methods for Numerical Analysis with R is intended for those who already know R but are interested in learning more about how the underlying algorithms work As such it is suitable for statisticians economists and engineers and others with a computational and numerical background     An Introduction to Numerical Analysis Kendall Atkinson, 1989-01-17 This edition of the standard introductory textbook on numerical analysis has been revised and updated to include optimization trigonometric interpolation and the fast Fourier transform numerical differentiation the method of lines and boundary value problems

Numerical Methods with Worked Examples Chris Woodford, C. Woodford, Chris Phillips, 1997-08-31 This book is for students following a module in numerical methods numerical techniques or numerical analysis It approaches the subject from a pragmatic viewpoint appropriate for the modern student The theory is kept to a minimum commensurate with comprehensive coverage of the subject and it contains abundant worked examples which provide easy understanding through a clear and concise theoretical treatment     Introduction to Numerical Analysis A. Neumaier, Arnold Neumaier, 2001-10 This textbook provides an introduction to constructive methods that provide accurate approximations to the solution of numerical problems using MATLAB     *Numerical Methods* J. Douglas Faires, Richard L. Burden, 1998 This text emphasizes the intelligent application of approximation techniques to the type of problems that commonly occur in engineering and the physical sciences The authors provide a sophisticated introduction to various appropriate approximation techniques they show students why the methods work what type of errors to expect and when an application might lead to difficulties and they provide information about the availability of high quality software for numerical approximation routines The techniques covered in this text are essentially the same as those covered in the Sixth Edition of these authors top selling Numerical Analysis text but the emphasis is much different In Numerical Methods Second Edition full mathematical justifications are provided only if they are concise and add to the understanding of the methods The emphasis is placed on describing each technique from an implementation standpoint and on convincing the student that the method is reasonable both mathematically and computationally     **Numerical Methods for Ordinary Differential Equations** J. C. Butcher, 2004-08-20 This new book updates the exceptionally popular Numerical Analysis of Ordinary Differential Equations This book is an indispensable reference for any researcher American Mathematical Society on the First Edition Features New

exercises included in each chapter Author is widely regarded as the world expert on Runge Kutta methods Didactic aspects of the book have been enhanced by interspersing the text with exercises Updated Bibliography

**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

**Classical and Modern Numerical Analysis** Azmy S. Ackleh,Edward James Allen,R. Baker Kearfott,Padmanabhan Seshaiyer,2009-07-20 Classical and Modern Numerical Analysis Theory Methods and Practice provides a sound foundation in numerical analysis for more specialized topics such as finite element theory advanced numerical linear algebra and optimization It prepares graduate students for taking doctoral examinations in numerical analysis The text covers the main areas of

Handbook of Numerical Analysis Philippe G. Ciarlet,Jacques Louis Lions,2002

**Nonlinear Methods in Numerical Analysis** A. Cuyt,L. Wuytack,1987-03-01 While most textbooks on Numerical Analysis discuss linear techniques for the solution of various numerical problems this book introduces and illustrates nonlinear methods It presents several nonlinear techniques resulting mainly from the use of Pad approximants and rational interpolants

**Analysis of Numerical Methods** Eugene Isaacson,Herbert Bishop Keller,1994-06-07 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 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

Analysis Raimer Kress,1998-04-17 An introduction into numerical analysis for students in mathematics physics and engineering Instead of attempting to exhaustively cover everything the goal is to guide readers towards the basic ideas and general principles by way of the main and important numerical methods The book includes the necessary basic functional analytic tools for the solid mathematical foundation of numerical analysis indispensable for any deeper study and understanding of numerical methods in particular for differential equations and integral equations The text is presented in a concise and easily understandable fashion so as to be successfully mastered in a one year course **A Friendly**

**Introduction to Numerical Analysis** Brian Bradie,2006 An introduction to the fundamental concepts and techniques of numerical analysis and numerical methods Application problems drawn from many different fields aim to prepare students to use the techniques covered to solve a variety of practical problems Numerical Analysis of Wavelet Methods A.

Cohen,2003-04-29 Since their introduction in the 1980 s wavelets have become a powerful tool in mathematical analysis with applications such as image compression statistical estimation and numerical simulation of partial differential equations One of their main attractive features is the ability to accurately represent fairly general functions with a small number of adaptively chosen wavelet coefficients as well as to characterize the smoothness of such functions from the numerical behaviour of these coefficients The theoretical pillar that underlies such properties involves approximation theory and function spaces and plays a pivotal role in the analysis of wavelet based numerical methods This book offers a self contained treatment of wavelets which includes this theoretical pillar and its applications to the numerical treatment of partial differential equations Its key features are 1 Self contained introduction to wavelet bases and related numerical algorithms from the simplest examples to the most numerically useful general constructions 2 Full treatment of the theoretical foundations that are crucial for the analysis of wavelets and other related multiscale methods function spaces linear and nonlinear approximation interpolation theory 3 Applications of these concepts to the numerical treatment of partial differential equations multilevel preconditioning sparse approximations of differential and integral operators adaptive discretization strategies **Numerical Analysis** Walter Gautschi,2011-12-06 Revised and updated this second edition of

Walter Gautschi's successful Numerical Analysis explores computational methods for problems arising in the areas of classical analysis approximation theory and ordinary differential equations among others Topics included in the book are

presented with a view toward stressing basic principles and maintaining simplicity and teachability as far as possible while subjects requiring a higher level of technicality are referenced in detailed bibliographic notes at the end of each chapter Readers are thus given the guidance and opportunity to pursue advanced modern topics in more depth Along with updated references new biographical notes and enhanced notational clarity this second edition includes the expansion of an already large collection of exercises and assignments both the kind that deal with theoretical and practical aspects of the subject and those requiring machine computation and the use of mathematical software Perhaps most notably the edition also comes with a complete solutions manual carefully developed and polished by the author which will serve as an exceptionally valuable resource for instructors

**Numerical Analysis** Richard L. Burden, J. Douglas Faires, Albert C. Reynolds, 1981

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