

# 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:

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

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## STANDARD ERROR:

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

## 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:  $y = a_0 + a_1 x$

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

Classic 4th order Runge-Kutta

Classic 4th order Runge-Kutta

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:  $\begin{bmatrix} 1 \\ 2 \end{bmatrix}, \begin{bmatrix} -2 \\ 1 \end{bmatrix}$

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

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

QR algorithm:  $A = Q R$

Householder transformation:  $H = I - 2 \frac{u u^T}{u^T u}$

Givens rotation:  $G = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix}$

Jacobi method:  $A = Q_1 Q_2 \dots Q_n R$

Schur decomposition:  $A = U T U^H$

Adams-Bashforth method:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Adams-Moulton method:  $y_{n+1} = y_n + \Delta t \phi(t_{n+1}, y_{n+1})$

Runge-Kutta method:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Heun's method:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Midpoint method:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Classical Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Implicit Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Symplectic Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Stiff Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Adaptive Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Variable step size Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Variable order Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Embedded Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

Multi-stage Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

High-order Runge-Kutta:  $y_{n+1} = y_n + \Delta t \phi(t_n, y_n)$

## PDE'S

Finite Difference Method

Central Difference

Forward Difference

Backward Difference

Implicit Method

Explicit Method

Stability Analysis

Convergence Analysis

Accuracy Analysis

Error Analysis

Boundary Conditions

Initial Conditions

Source Terms

Sink Terms

Reaction Terms

Diffusion Terms

Convection Terms

Pressure Terms

Temperature Terms

Velocity Terms

Acceleration Terms

Angular Velocity Terms

Angular Acceleration Terms

Torque Terms

Power Terms

Energy Terms

Mass Terms

Charge Terms

Current Terms

Voltage Terms

Resistance Terms

Capacitance Terms

Inductance Terms

Frequency Terms

Wavelength Terms

Wave Number Terms

Phase Terms

Amplitude Terms

Frequency Response Terms

Impedance Terms

Admittance Terms

Transfer Function Terms

Block Diagram Terms

Signal Flow Graph Terms

State Space Terms

Transfer Matrix Terms

Block Matrix Terms

State Matrix Terms

Input Matrix Terms

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# Numerical Methods Numerical Methods

**Eugene Isaacson, Herbert Bishop Keller**

## **Numerical Methods Numerical Methods:**

**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 Numerical Methods that Work Forman S. Acton, 1990 A commonsense approach to numerical algorithms for the solution of equations

**Numerical Methods** M. K. Jain, Satteluri R. K. Iyengar, R. K. Jain, 2007 Is An Outline Series Containing Brief Text Of Numerical Solution Of Transcendental And Polynomial Equations System Of Linear Algebraic Equations And Eigenvalue Problems Interpolation And Approximation Differentiation And Integration Ordinary Differential Equations And Complete Solutions To About 300 Problems Most Of These Problems Are Given As Unsolved Problems In The Authors Earlier Book User Friendly Turbo Pascal Programs For Commonly Used Numerical Methods Are Given In The Appendix This Book Can Be Used As A Text Help Book Both By Teachers And Students

**Numerical Methods for Ordinary Differential Equations** David F. Griffiths, Desmond J. Higham, 2010-11-11 Numerical Methods for Ordinary Differential Equations is a self contained introduction to a fundamental field of numerical analysis and scientific computation Written for undergraduate students with a mathematical background this book focuses on the analysis of numerical methods without losing sight of the practical nature of the subject It covers the topics traditionally treated in a first course but also highlights new and emerging themes Chapters are broken down into lecture sized pieces motivated and illustrated by numerous theoretical and computational examples Over 200 exercises are provided and these are starred according to their degree of difficulty Solutions to all exercises are available to authorized instructors The book covers key foundation topics o Taylor series methods o Runge Kutta methods o Linear multistep methods o Convergence o Stability and a range of modern themes o Adaptive stepsize selection o Long term dynamics o Modified equations o Geometric integration o Stochastic differential equations The prerequisite of a basic university level calculus class is assumed although appropriate background results are also summarized in appendices A dedicated website for the book containing extra information can be found via [www.springer.com](http://www.springer.com) 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 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:** Ram, 2010 Numerical Methods is a mathematical tool used by engineers and mathematicians to do scientific calculations. It is used to find solutions to applied problems where ordinary analytical methods fail. This book is intended to serve for the needs of co

**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 and Software** David Kahaner, Cleve B. Moler, Stephen Nash, 1988 Mathematics of Computing Numerical Analysis *Numerical Methods for Differential Equations* J.R. Dormand, 2018-05-04 With emphasis on modern techniques Numerical Methods for Differential Equations A Computational Approach covers the development and application of methods for the numerical solution of ordinary differential equations. Some of the methods are extended to cover partial differential equations. All techniques covered in the text are on a program disk included with the book and are written in Fortran 90. These programs are ideal for students, researchers and practitioners because they allow for straightforward application of the numerical methods described in the text. The code is easily modified to solve new systems of equations. Numerical Methods for Differential Equations A Computational Approach also contains a reliable and inexpensive global error code for those interested in global error estimation. This is a valuable text for students who will find the derivations of the numerical methods extremely helpful and the programs themselves easy to use. It is also an excellent reference and source of software for researchers and practitioners who need computer solutions to differential equations.

**Numerical Methods for Scientists and Engineers** Richard W. Hamming, Richard Wesley Hamming, 1986-01-01 This inexpensive paperback edition of a groundbreaking text stresses frequency approach in coverage of algorithms polynomial approximation Fourier approximation exponential approximation and other topics. Revised and enlarged 2nd edition.

**Numerical Methods For Scientific And Engineering Computation** M.K. Jain, 2003

**Numerical Methods for Engineers and Scientists** Joe D. Hoffman, Steven Frankel, 2018-10-03 Emphasizing the finite difference approach for solving differential equations the second edition of Numerical Methods for Engineers and Scientists presents a

methodology for systematically constructing individual computer programs Providing easy access to accurate solutions to complex scientific and engineering problems each chapter begins with objectives a discussion of a representative application and an outline of special features summing up with a list of tasks students should be able to complete after reading the chapter perfect for use as a study guide or for review The AIAA Journal calls the book a good solid instructional text on the basic tools of numerical analysis

**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

*Numerical Methods, with Applications in the Biomedical Sciences* E. H. Twizell, 1988

*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 Methods Rajesh Kumar Gupta, 2019-05-09 Offers a comprehensive textbook for a course in numerical methods numerical analysis and numerical techniques for undergraduate engineering students

Numerical Methods S. Balachandra Rao, C. K. Shantha, 2004 The book discusses the important numerical methods which are frequently used in mathematical physical engineering and even biological sciences It will serve as an ideal textbook for the undergraduate and diploma courses The revised edition has a section on C and programs in C

Discrete Numerical Methods in Physics and Engineering Greenspan, 1974-05-31 Discrete Numerical Methods in Physics and Engineering

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

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