

NUMERICAL METHODS

C / RAPPY EXAM 12 / 11/19 / 2022 [20.000]

LEAST SQUARES REGRESSION

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



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

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

$$a_0 = \frac{\sum y_i}{n} \quad a_1 = \frac{\sum x_i y_i - \frac{(\sum x_i)(\sum y_i)}{n}}{\sum x_i^2 - \frac{(\sum x_i)^2}{n}}$$

STANDARD ERROR:

$$S_{y_1} = \sqrt{\frac{S_r}{n-2}} \quad S_{y_2} = \sqrt{\frac{S_r(y_2 - \bar{y})^2}{n-2}}$$

STANDARD DEVIATION:

$$S_y = \sqrt{\frac{S_r}{n-1}} \quad S_x = \sqrt{\frac{2(y_2 - \bar{y})^2}{n-1}}$$

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

POLYNOMIAL QUADRATIC REGRESSION:



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

Take derivatives of S_r to find the error.

$$\frac{\partial S_r}{\partial a_0} = -2(\sum y_i - \sum a_0 - a_1 \sum x_i - a_2 \sum x_i^2) = 0$$

$$\frac{\partial S_r}{\partial a_1} = -2(\sum x_i y_i - \sum a_0 \sum x_i - a_1 \sum x_i^2 - a_2 \sum x_i^3) = 0$$

$$\frac{\partial S_r}{\partial a_2} = -2(\sum x_i^2 y_i - \sum a_0 \sum x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4) = 0$$

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

Use Gauss-Jordan elimination to solve for a_0, a_1, a_2 .

INTERPOLATION

Use a polynomial $P(x)$



ODE'S

Euler's Method

$$\frac{dy}{dx} = f(x, y) \quad y_{n+1} = y_n + f(x_n, y_n) \Delta x$$

Runge-Kutta Method

$$y' = f(x, y)$$

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

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

$$k_3 = f(x_n + \Delta x, y_n + \Delta x k_2)$$

$$y_{n+1} = y_n + \Delta x \left(\frac{1}{6} k_1 + \frac{4}{6} k_2 + \frac{1}{6} k_3 \right)$$

Taylor Series:
 $y(x+\Delta x) = y(x) + \Delta x y'(x) + \frac{\Delta x^2}{2} y''(x) + \dots$
 $y(x+\Delta x) = y(x) + f(x, y) \Delta x$

Classic 4th order Runge-Kutta

$$y_{n+1} = y_n + \Delta x \left(\frac{1}{4} k_1 + \frac{3}{4} k_2 + 2k_3 + k_4 \right)$$

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

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

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

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

PDE'S

Finite Difference Method



EIGEN VALUES

$\lambda = \text{Eigen Value}$

Example: 2×2

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \lambda x_1 \\ \lambda x_2 \end{bmatrix}$$

The determinant:

$$\begin{bmatrix} a_{11} - \lambda & a_{12} \\ a_{21} & a_{22} - \lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

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

$$D(x) = \det \begin{bmatrix} a - \lambda & b \\ c & d - \lambda \end{bmatrix} = 0$$

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

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

Find Eigen Vectors with given

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \lambda x_1 \\ \lambda x_2 \end{bmatrix}$$

$$\begin{cases} (a - \lambda)x_1 + bx_2 = 0 \\ cx_1 + (d - \lambda)x_2 = 0 \end{cases}$$

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \lambda x_1 \\ \lambda x_2 \end{bmatrix}$$

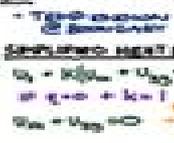
$$\begin{cases} -\lambda x_1 + \lambda x_2 = 0 & x_1 = x_2 \\ (x_1 + -\lambda x_2) = 0 & x_1 = \lambda x_2 \\ \lambda x_1 = \lambda x_2 & x_1 = x_2 \end{cases}$$

1D Heat Conduction



$$u_{i,j}(t) = u_{i,j}(t-\Delta t) - 2\alpha u_{i,j}(t-\Delta t) + \alpha(u_{i-1,j}(t-\Delta t) + u_{i+1,j}(t-\Delta t))$$

2D Heat Conduction



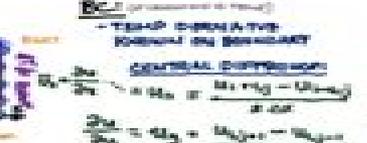
$$u_{i,j}(t) = u_{i,j}(t-\Delta t) - 2\alpha u_{i,j}(t-\Delta t) + \alpha(u_{i-1,j}(t-\Delta t) + u_{i+1,j}(t-\Delta t) + u_{i,j-1}(t-\Delta t) + u_{i,j+1}(t-\Delta t))$$

1D Advection



$$u_{i,j}(t) = u_{i-1,j}(t-\Delta t) - \alpha u_{i-1,j}(t-\Delta t) + \alpha u_{i,j}(t-\Delta t)$$

2D Advection



$$u_{i,j}(t) = u_{i-1,j-1}(t-\Delta t) - \alpha u_{i-1,j-1}(t-\Delta t) + \alpha u_{i,j}(t-\Delta t)$$

5th Rank of a Matrix



$$\begin{bmatrix} 0 & -1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

[A] MATRIX: $u_{i,j}(t) = u_{i,j}(t-\Delta t) - 2\alpha u_{i,j}(t-\Delta t) + \alpha(u_{i-1,j}(t-\Delta t) + u_{i+1,j}(t-\Delta t) + u_{i,j-1}(t-\Delta t) + u_{i,j+1}(t-\Delta t))$

TOP: $-u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2\alpha u_{i,j} = -2\alpha u_{i,j}$

RIGHT: $-u_{i,j-1} - u_{i,j+1} + 4u_{i,j} - 2\alpha u_{i,j} = -2\alpha u_{i,j}$

LEFT: $-u_{i-1,j} - u_{i+1,j} + 4u_{i,j} - 2\alpha u_{i,j} = -2\alpha u_{i,j}$

FINITE DIFFS: CENTERED FINITE-DIFFERENCED DERIVATIVE

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

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

Numerical Methods For Mathematics Science And Engineering

Emilie Sanchez



Numerical Methods For Mathematics Science And Engineering:

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

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Numerical Analysis For Applied Mathematics, Science, And Engineering Donald Greenspan, Vincenzo Casulli, 1988-01-21 This book is designed for a first course in numerical analysis It differs considerably from other such texts in its choice of topics

Numerical Methods for Scientists and Engineers Richard Hamming, 2012-04-25 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

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Numerical Methods in Engineering and Applied Science Bruce Irons, Nigel Shrive, 1987

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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

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

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Numerical Methods for Computer Science, Engineering, and Mathematics John H. Mathews,1987 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 *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

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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 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 11 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

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

Numerical Methods for Engineers and Scientists J. N. Sharma (M.A.), 2004 The desire for numerical answers to applied problems has increased manifold with the advances made in various branches of science and engineering and rapid development of high speed digital computers Although numerical methods have always been useful their role in the present day scientific computations and research is of fundamental importance numerous distinguishing features The contents of the book have been organized in a logical order and the topics are discussed in a systematic manner concepts algorithms and numerous exercises at the end of each chapter helps students in problem solving both manually and through computer programming an exhaustive bibliography and an appendix containing some important and useful iterative methods for the solution of nonlinear complex equations

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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