

NUMERICAL METHODS

C / KAPPA 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.

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

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

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

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

Matrix inversion to find coefficients.

INTERPOLATION

Use a polynomial fit:



ODE'S

Euler's Method:
 $y_{i+1} = y_i + f(x_i, y_i) \Delta x$

Runge-Kutta Method:

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

$$y_{i+1} = y_i + \frac{\Delta x}{2} [f(x_i, y_i) + f(x_{i+1}, y_{i+1})]$$

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

CLASSIC 4th ORDER Runge-Kutta:

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

$$k_1 = f(x_i, y_i)$$

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

$$k_3 = f(x_i + \frac{1}{2}\Delta x, y_i + \Delta x k_1)$$

$$k_4 = f(x_i + \Delta x, y_i + \Delta x k_1)$$

PDE'S

FINITE DIFFERENCE METHOD:



EIGEN VALUES

$\lambda = \text{eigen value}$

Example: 2×2

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

The determinant:

$$\begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \frac{1}{\det(A)} \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} -b \\ c \end{bmatrix}$$

$$\det(A) = \frac{1}{\det(A)} \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} -b \\ c \end{bmatrix}$$

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

Find eigen value from:

$$\begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$(a-\lambda)x_1 + bx_2 = 0 \Rightarrow x_1 = -\frac{b}{a-\lambda}x_2$$

$$cx_1 + (d-\lambda)x_2 = 0 \Rightarrow x_1 = -\frac{(d-\lambda)}{c}x_2$$

$$x_1 = \begin{bmatrix} - \\ \end{bmatrix}$$

$$\begin{bmatrix} a-\lambda & b \\ c & d-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$-ax_1 + bx_2 = 0 \Rightarrow x_1 = \frac{b}{a}x_2$$

$$(x_1 + -\lambda x_2) = 0 \Rightarrow x_1 = \lambda x_2$$

$$x_1 = \begin{bmatrix} \lambda \\ 1 \end{bmatrix}$$

$$C(A) = \begin{bmatrix} \lambda \\ 1 \end{bmatrix}$$

1D Heat Conduction



$$u_{i+1}(t) = u_i(t) - \alpha \Delta x (u_{i+1} - u_i) + \alpha \Delta x (u_i - u_{i-1})$$

$$u_{i+1}(t) = u_i(t) + \alpha \Delta x (u_{i+1} - u_i) + \alpha \Delta x (u_i - u_{i-1})$$

$$u_{i+1}(t) = u_i(t) + \alpha \Delta x (u_{i+1} - u_i) + \alpha \Delta x (u_i - u_{i-1})$$

$$u_{i+1}(t) = u_i(t) + \alpha \Delta x (u_{i+1} - u_i) + \alpha \Delta x (u_i - u_{i-1})$$

2D Heat Conduction



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

3D Heat Conduction



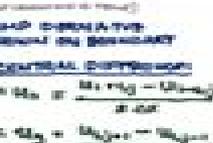
$$u_{i+1,j+1,k} = u_{i,j,k} + \alpha \Delta x (u_{i+1,j+1,k} - u_{i,j+1,k}) + \alpha \Delta x (u_{i,j+1,k} - u_{i-1,j+1,k}) + \alpha \Delta y (u_{i,j+1,k} - u_{i,j,k}) + \alpha \Delta y (u_{i,j,k} - u_{i,j-1,k}) + \alpha \Delta z (u_{i,j+1,k} - u_{i,j+1,k-1}) + \alpha \Delta z (u_{i,j+1,k-1} - u_{i,j+1,k-2})$$

1D Heat Conduction



$$u_{i+1} = u_i + \frac{\alpha \Delta x}{2\Delta x} (u_{i+1} - u_i) + \frac{\alpha \Delta x}{2\Delta x} (u_i - u_{i-1})$$

2D Heat Conduction



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

3D Heat Conduction



$$u_{i+1,j+1,k+1} = u_{i,j,k} + \frac{\alpha \Delta x}{2\Delta x} (u_{i+1,j+1,k+1} - u_{i,j+1,k+1}) + \frac{\alpha \Delta x}{2\Delta x} (u_{i,j+1,k+1} - u_{i-1,j+1,k+1}) + \frac{\alpha \Delta y}{2\Delta y} (u_{i,j+1,k+1} - u_{i,j,k+1}) + \frac{\alpha \Delta y}{2\Delta y} (u_{i,j,k+1} - u_{i,j-1,k+1}) + \frac{\alpha \Delta z}{2\Delta z} (u_{i,j+1,k+1} - u_{i,j+1,k}) + \frac{\alpha \Delta z}{2\Delta z} (u_{i,j+1,k} - u_{i,j+1,k-1})$$

5th Rank of A Matrix

$$\begin{bmatrix} 0 & -1 & 0 & -1 & 0 & -1 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \end{bmatrix} = 0$$

$$u_{i+1,j} = u_{i,j} - 2\alpha \Delta x u_i$$

TRUNCATION ERROR

Centered finite-difference formula:

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

$$f'(x) = \frac{f(x+\Delta x) - f(x-\Delta x)}{2\Delta x} - \frac{1}{6} f'''(x) \Delta x^2 + \dots$$

Numerical Analysis Using R

Ahmed K. Noor, Harvey G. McComb

Numerical Analysis Using R:

Using R for Numerical Analysis in Science and Engineering Victor A. Bloomfield, 2018-09-03 Instead of presenting the standard theoretical treatments that underlie the various numerical methods used by scientists and engineers *Using R for Numerical Analysis in Science and Engineering* shows how to use R and its add on packages to obtain numerical solutions to the complex mathematical problems commonly faced by scientists and engineers This practical guide to the capabilities of R demonstrates Monte Carlo stochastic deterministic and other numerical methods through an abundance of worked examples and code covering the solution of systems of linear algebraic equations and nonlinear equations as well as ordinary differential equations and partial differential equations It not only shows how to use R's powerful graphic tools to construct the types of plots most useful in scientific and engineering work but also Explains how to statistically analyze and fit data to linear and nonlinear models Explores numerical differentiation integration and optimization Describes how to find eigenvalues and eigenfunctions Discusses interpolation and curve fitting Considers the analysis of time series *Using R for Numerical Analysis in Science and Engineering* provides a solid introduction to the most useful numerical methods for scientific and engineering data analysis using R

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

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Encyclopedia of Environmental Change John A Matthews, 2013-12-13 Accessibly written by a team of international authors the Encyclopedia of Environmental Change provides a gateway to the complex facts concepts techniques methodology and philosophy of environmental change This three volume set illustrates and examines topics within this dynamic and rapidly changing interdisciplinary field The encyclopedia includes all of the following aspects of environmental change Diverse evidence of environmental change including climate change and changes on land and in the oceans Underlying natural and anthropogenic causes and mechanisms Wide ranging local regional and global impacts from the polar regions to the tropics Responses of geo ecosystems and human environmental systems in the face of past present and future environmental change Approaches methodologies and techniques used for reconstructing dating monitoring modelling projecting and predicting change Social economic and political dimensions of environmental issues environmental conservation and management and environmental policy Over 4 000 entries explore the following key themes and more Conservation Demographic change Environmental management Environmental policy Environmental security Food security Glaciation Green Revolution Human impact on environment Industrialization Landuse change Military impacts on environment Mining and mining impacts Nuclear energy Pollution Renewable resources Solar energy Sustainability Tourism Trade Water resources Water security Wildlife conservation The comprehensive coverage of terminology includes layers of entries ranging from one line definitions to short essays making this an invaluable companion for any student of physical geography environmental geography or environmental sciences

Advanced Mathematical Tools In Metrology - Proceedings Of The International Workshop Nicola Bellomo, Patrizia Ciarlini, Maurice G Cox, Roberto Monaco, Franco Pavese, 1994-05-18 Since its reform and opening up China has experienced unprecedented social and economic development It is important to understand the biggest and fastest growing economy s policy and strategy As a key director in Party School of the Central Committee of the Communist Party of China the author proposes a development path and reform strategies for China in the next three decades This book suggests reform strategies not only for the economic structure but also for the political system in China The author makes a sound analysis and exposition of Chinese dream which reflects the vision of a better life in the future and the main indicators of social change The book investigates China s development path political system economic structure people s livelihood etc and

suggests long term strategies for China in this regard

Computational Methods in Nonlinear Structural and Solid

Mechanics Ahmed K. Noor,Harvey G. McComb,2014-05-20 Computational Methods in Nonlinear Structural and Solid Mechanics covers the proceedings of the Symposium on Computational Methods in Nonlinear Structural and Solid Mechanics The book covers the development of efficient discretization approaches advanced numerical methods improved programming techniques and applications of these developments to nonlinear analysis of structures and solids The chapters of the text are organized into 10 parts according to the issue they tackle The first part deals with nonlinear mathematical theories and formulation aspects while the second part covers computational strategies for nonlinear programs Part 3 deals with time integration and numerical solution of nonlinear algebraic equations while Part 4 discusses material characterization and nonlinear fracture mechanics and Part 5 tackles nonlinear interaction problems The sixth part discusses seismic response and nonlinear analysis of concrete structure and the seventh part tackles nonlinear problems for nuclear reactors Part 8 covers crash dynamics and impact problems while Part 9 deals with nonlinear problems of fibrous composites and advanced nonlinear applications The last part discusses computerized symbolic manipulation and nonlinear analysis software systems The book will be of great interest to numerical analysts computer scientists structural engineers and other professionals concerned with nonlinear structural and solid mechanics

Mathematical Programming The State of the Art A. Bachem,M.

Grötschel,B. Korte,2012-12-06 In the late forties Mathematical Programming became a scientific discipline in its own right Since then it has experienced a tremendous growth Beginning with economic and military applications it is now among the most important fields of applied mathematics with extensive use in engineering natural sciences economics and biological sciences The lively activity in this area is demonstrated by the fact that as early as 1949 the first Symposium on Mathematical Programming took place in Chicago Since then mathematical programmers from all over the world have gathered at the international symposia of the Mathematical Programming Society roughly every three years to present their recent research to exchange ideas with their colleagues and to learn about the latest developments in their own and related fields In 1982 the XI International Symposium on Mathematical Programming was held at the University of Bonn W Germany from August 23 to 27 It was organized by the Institut für Ökonometrie und Operations Research of the University of Bonn in collaboration with the Sonderforschungsbereich 21 of the Deutsche Forschungsgemeinschaft This volume constitutes part of the outgrowth of this symposium and documents its scientific activities Part I of the book contains information about the symposium welcoming addresses lists of committees and sponsors and a brief review about the Fulerson Prize and the Dantzig Prize which were awarded during the opening ceremony

Library of Congress Subject Headings Library of

Congress,2001 *University of California Union Catalog of Monographs Cataloged by the Nine Campuses from 1963*

Through 1967: Subjects University of California (System). Institute of Library Research,University of California,

Berkeley,1972 Moving Finite Element Method Maria do Carmo Coimbra,Alirio Egidio Rodrigues,Jaime Duarte

Rodrigues,Rui Jorge Mendes Robalo,Rui Manuel Pires Almeida,2016-11-30 This book focuses on process simulation in chemical engineering with a numerical algorithm based on the moving finite element method MFEM It offers new tools and approaches for modeling and simulating time dependent problems with moving fronts and with moving boundaries described by time dependent convection reaction diffusion partial differential equations in one or two dimensional space domains It provides a comprehensive account of the development of the moving finite element method describing and analyzing the theoretical and practical aspects of the MFEM for models in 1D 1D 1d and 2D space domains Mathematical models are universal and the book reviews successful applications of MFEM to solve engineering problems It covers a broad range of application algorithm to engineering problems namely on separation and reaction processes presenting and discussing relevant numerical applications of the moving finite element method derived from real world process simulations **Critical Phenomena** F. J. W. Hahne,2005-06-30 **Catalogue of the Library of the Surgeon General's Office, U. S. Army** ,1873 Catalogue of the Library of the Surgeon General's Office, United States Army United States Army. Library of the Surgeon General's Office (Washington).,1873 **Scientific and Technical Aerospace Reports** ,1985 **The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science** ,1922 **Account of the Operations of the Great Trigonometrical Survey of India** Survey of India. Trigonometrical Branch,1901 **Periodic orbits and miscellaneous papers. 1911** Sir George Howard Darwin,1911 **U.S. Government Research & Development Reports** ,1965 **Report of the ... Meeting of the British Association for the Advancement of Science** ,1884

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