

# 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:

$$S_{y_1} = \sqrt{\frac{S_r}{n-2}} \quad S_{y_2} = \sqrt{\frac{S_r (1-x_i^2)}{n-2}}$$

## STANDARD DEVIATION:

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

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

## 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.

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

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

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

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

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

## INTERPOLATION

Use a polynomial  $P(x)$



## ODE'S

### Euler's Method

$$\frac{dy}{dx} = f(x,y) \quad y_{i+1} = y_i + f(x_i, y_i) \Delta x$$

### Runge-Kutta Method

$$\frac{dy}{dx} = f(x,y)$$

$$y' = \frac{y^2 + 2x}{2} \quad f(x,y) = \frac{y^2 + 2x}{2}$$

$$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_i) + f(x_i, y_{i+1}) + f(x_{i+1}, y_{i+1})}{4} \Delta x$$

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

### Classic 4th order Runge-Kutta

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

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

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

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

$$k_4 = f(x_i + \Delta x, y_i + k_3 \Delta x)$$

## PDE'S

### Finite Difference Method



## EIGEN VALUES

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \quad \det(A - \lambda I) = 0$$

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

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

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

Single 2x2:

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \quad \det(A - \lambda I) = 0$$

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

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

Two eigen values with same eigenvector:

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

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

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

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

**RIGHT BOUNDARY BC:**  $T_0 = 0$

**LEFT BOUNDARY BC:**  $T_N = 0$

**TOP BOUNDARY BC:**  $T_{i,0} = 0$

**BOTTOM BOUNDARY BC:**  $T_{i,N} = 0$

**CENTRAL DIFFERENCE:**  $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1,j} - 2T_{i,j} + T_{i-1,j}}{\Delta x^2}$

**RIGHT BOUNDARY BC:**  $\frac{\partial T}{\partial x} = 0 \Rightarrow \frac{T_{i+1,j} - T_{i,j}}{\Delta x} = 0 \Rightarrow T_{i+1,j} = T_{i,j}$

**LEFT BOUNDARY BC:**  $\frac{\partial T}{\partial x} = 0 \Rightarrow \frac{T_{i,j} - T_{i-1,j}}{\Delta x} = 0 \Rightarrow T_{i,j} = T_{i-1,j}$

**TOP BOUNDARY BC:**  $\frac{\partial T}{\partial y} = 0 \Rightarrow \frac{T_{i,j+1} - T_{i,j}}{\Delta y} = 0 \Rightarrow T_{i,j+1} = T_{i,j}$

**BOTTOM BOUNDARY BC:**  $\frac{\partial T}{\partial y} = 0 \Rightarrow \frac{T_{i,j} - T_{i,j-1}}{\Delta y} = 0 \Rightarrow T_{i,j} = T_{i,j-1}$

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**[A] MATRIX:**

$$-2u_{i,j} + u_{i+1,j} + u_{i-1,j} - u_{i,j+1} - u_{i,j-1} = -2\Delta x^2 \Delta T_{i,j}$$

$$-2u_{i,j} + 4u_{i,j} - u_{i+1,j} - u_{i-1,j} = -2\Delta x^2 \Delta T_{i,j}$$

$$-2u_{i,j} + 4u_{i,j} - u_{i,j+1} - u_{i,j-1} = -2\Delta x^2 \Delta T_{i,j}$$

$$-u_{i,j} - u_{i,j+1} + 4u_{i,j} - 2u_{i,j-1} = -2\Delta x^2 \Delta T_{i,j}$$

$$-u_{i,j} - u_{i,j-1} + 4u_{i,j} - 2u_{i,j+1} = -2\Delta x^2 \Delta T_{i,j}$$

**FINITE DIFFERENCE:**

**CENTRAL FINITE-DIFFERENCE 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 Analysis Using R

**John A Matthews**



## **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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can be adapted to solve wide ranges of problems and illustrates them in the increasingly popular open source computer language R allowing integration with more statistically based methods The book begins with standard techniques followed by an overview of high resolution flux limiters and WENO to solve problems with solutions exhibiting high gradient phenomena Meshless methods using radial basis functions are then discussed in the context of scattered data interpolation and the solution of PDEs on irregular grids Three detailed case studies demonstrate how numerical methods can be used to tackle very different complex problems With its focus on practical solutions to real world problems this book will be useful to students and practitioners in all areas of science and engineering especially those using R

**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

*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

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*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 Fulkeron Prize and the Dantzig Prize which were awarded during the opening ceremony

Library of Congress Subject Headings Library of Congress, 2001 *Scientific and Technical Aerospace Reports*, 1985  
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 Shipbuilding and Shipping Record, 1927 **Shipbuilding & Shipping Record**, 1927 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 **Catalogue of the Library of the Surgeon General's Office, U. S. Army**, 1873 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

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