NUMERICAL METHODS

r/KAFFT | EXAM 2 | 11/14 / 2021 | 26 PAGES

LEAST SQUARES REGRESSION

GOAL: MINIMIZE THE SUM OF THE SQUARE OF THE RESIDUAL ERROR

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

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

$a_0 = \frac{\sum y_i}{n} - a_1 \frac{\sum x_i}{n} \rightarrow a_0 = \bar{y} - a_1 \bar{x}$

STANDARD ERROR:

$S_{y/x} = \sqrt{\frac{S_r}{n-2}}$ $S_{y/x} = \sqrt{\frac{\sum (y_i - y^{est})^2}{n-2}}$

STND DEVIATION:

$S_y = \sqrt{\frac{S_t}{n-1}}$ $S_y = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n-1}}$

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

$y = a_0 + a_1 x$

INTERPOLATION

- USE A POLYNOMIAL FIT!

LINEAR	DEGREE 2	DEGREE 3	DEGREE 4
2 PTS	3 PTS	4 PTS	n+1 PTS
2 UNKNOWNS	3 UNKNOWNS	4 UNKNOWNS	n+1 UNKNOWNS

$P_n(x) = a_0 + a_1 x + a_2 x^2 + \cdots + a_n x^n$

ORDER	TURNS
n=1	0
n=2	1
n=3	2
n=4	3
n=n	n-1

SPLINES:

$m_i = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i}$

POLYNOMIAL (QUADRATIC) REGRESSION:

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

- TAKE DERIVATIVE OF S_r TO FIND MIN ERROR

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

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

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

$\sum a_0 = a_0 n$

$\begin{bmatrix} n & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum x_i y_i \\ \sum x_i^2 y_i \end{bmatrix} \rightarrow [A][X] = [B]$

[A] [X] [B]

$S_{y/x} = \sqrt{\frac{S_r}{n-(m+1)}}$ — data points; m = order of polynomial

$r^2 = \frac{S_t - S_r}{S_t}$ — coefficient of determination

ODE'S

- EULER'S METHOD (FORWARD EULER)

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

- HEUN'S METHOD:

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

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

$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1}^0)}{2}\Delta x$ (CORRECTOR)

$\frac{dy_{i+1}}{dx} = y'_{i+1} = f(x_{i+1}, y_{i+1}^0)$

$\frac{dy_i}{dx} = y'_i = f(x_i, y_i)$

$y' = \frac{y'_i + y'_{i+1}}{2} = \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1}^0)}{2}$

$y_{i+1} = y_i + \frac{f(x_i, y_i) + f(x_{i+1}, y_{i+1}^0)}{2}\Delta x$ (CORRECTOR)

- TAYLOR SERIES:

$y(x+\Delta x) = y(x) + \sum_{n=1}^{\infty} \frac{f^n(x)}{n!}(\Delta x)^n$

$y(x+\Delta x) = y(x) + f(x,y)\Delta x$

CLASSIC 1ST ORDER RUNGE-KUTTA:

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

$k_1 = f(x_i, y_i)$

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

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

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

DORMAND-PRINCE RUNGE-KUTTA:

$y_{n+1} = y_n + \Delta x \sum_{i=1}^{s} b_i k_i$ (ORDER 5 METHOD)

$y_{n+1} = y_n + \Delta x \sum_{i=1}^{s} a_i k_i$ (ORDER 4 METHOD)

PDE'S

- FINITE DIFFERENCE METHOD:

DIRICHLET BOUNDARY CONDITIONS

INSULATED OR CONVECTIVE THERMOCOUPLE

TEMPERATURE

EIGEN VALUES

λ = EIGEN VALUE

EXAMPLE:

$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

THE SAME!

$\begin{bmatrix} a_{11}-\lambda & a_{12} & a_{13} \\ a_{21} & a_{22}-\lambda & a_{23} \\ a_{31} & a_{32} & a_{33}-\lambda \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

SIMPLE 2x2:

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

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

NOTE: $\det(A) \neq 0$

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

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

FIND EIGEN VALUES FIRST

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

$1x_1 + 1x_2 = 0$

$1x_1 + 1x_2 = 0$

$x_1 = -x_2$

$x_2 = -x_1$

$x_1 = x_2$

- EIGEN VECTOR

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

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

$-1x_1 + 1x_2 = 0$

$1x_1 + -1x_2 = 0$

$x_1 = x_2$

$x_2 = x_1$

- ZERO EQUATION

$[x_1] = \begin{bmatrix} : \\ : \end{bmatrix}$

PROJECT:

THE SOLID + LIQUID

T_{BOTTOM}

T_{TOP}

$L = 5$

$T = 0°C$

$R_{in} = 2$

$R_{out} = 3°C$

$k = 500 \frac{W}{m \cdot K}$ (STEEL)

- CENTRAL DIFFERENCE

$u_{xx}(x,y) = \frac{u(x-\Delta x, y) - 2u(x,y) + u(x+\Delta x, y)}{\Delta x^2}$

$u_{yy}(x,y) = \frac{u(x, y-\Delta y) - 2u(x,y) + u(x, y+\Delta y)}{\Delta y^2}$

BC:

- TEMP KNOWN AT BOUNDARY

SIMPLIFIED HEAT EQN:

$0 = k(u_{xx} + u_{yy} + u_{zz}) + q$

IF $q = 0$ & $k = 1$

$u_{xx} + u_{yy} = 0$

NEUMANN:

BC:

- TEMP DERIVATIVE KNOWN AT BOUNDARY

CENTRAL DIFFERENCE:

$\frac{\partial u}{\partial x} = u_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$

$\frac{\partial u}{\partial y} = u_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta x}$

RIGHT NEUMANN B.C.

$\frac{\partial u}{\partial x} = u_x = \frac{u_{i+1,j} - u_{i-1,j}}{2\Delta x}$

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

BOTTOM NEUMANN B.C.

$\frac{\partial u}{\partial y} = u_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta x}$

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

TOP NEUMANN BC

$\frac{\partial u}{\partial y} = u_y = \frac{u_{i,j+1} - u_{i,j-1}}{2\Delta x}$

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

LEFT NEUMANN B.C.

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

5TH ROW OF A MATRIX

- RESULT MUST BE EQUAL TO ZERO!

$\begin{bmatrix} 0 & -1 & 0 & -1 & 4 & -1 & 0 & -1 & 0 \end{bmatrix} [u] = 0$

LEFT | BELOW | MIDDLE | ABOVE | RIGHT

[A] MATRIX:

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

LEFT:

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

THIS CHANGED

RIGHT:

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

THIS CHANGED

BOTTOM:

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

THIS CHANGED

TOP:

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

THIS CHANGED

FDC EQNS:

CENTERED FINITE-DIFFERENCE APPROXIMATION

FIRST:

$f'(x_i) = \frac{f(x_{i+1}) - f(x_{i-1})}{2\Delta x}$

$f'(x_i) = \frac{-f(x_{i+2}) + 8f(x_{i+1}) - 8f(x_{i-1}) + f(x_{i-2})}{12\Delta x}$

Numerical Analysis Using R

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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 **Numerical Analysis Using R : Solutions to ODEs and PDEs** Graham W Griffiths,2016 This book presents the latest numerical solutions to initial value problems and boundary value problems described by ODEs and PDEs The author offers practical methods that 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 Numerical Analysis Using R Graham W. Griffiths,2016-04-26 This book presents the latest numerical solutions to initial value problems and boundary value problems described by ODEs and PDEs The author offers practical methods that

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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 Mathe matical Programming took place in Chicago Since then mathematical programmers from all over the world have gath ered at the intfrnational 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 fUr Okonometrie und Operations Re search of the University of Bonn in collaboration with the Sonderforschungs bereich 21 of the Deutsche Forschungsgemeinschaft This volume constitutes part of the outgrowth of this symposium and docu ments 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 Ful kerson 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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