

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.



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

Residual Error = $y_i - \hat{y}_i$

$$a_0 = \frac{\sum y_i - a_1 \sum x_i}{n}$$

$$a_0 = \frac{\sum y_i}{n} - a_1 \frac{\sum x_i}{n}$$

STANDARD ERROR:

$$S_{y_1} = \sqrt{\frac{\sum y_i^2}{n-2}} \quad S_{y_2} = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n-2}}$$

STANDARD DEVIATION:

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

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

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 minimum

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

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

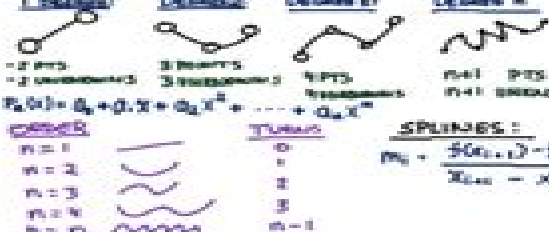
$$\frac{\partial S_r}{\partial a_2} = -2(\sum y_i x_i^2 - \sum a_0 \sum x_i^2 - a_1 \sum x_i^3 - a_2 \sum x_i^4) = 0$$

$$\begin{bmatrix} \sum x_i^0 & \sum x_i^1 & \sum x_i^2 \\ \sum x_i^1 & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \end{bmatrix}$$

Matrix inversion

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

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

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

$$y_1 = 1, y_2 = 2$$

$$y_3 = \frac{y_1^2 + 2x_1}{2} = \frac{1 + 2(1)}{2} = 1.5$$

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

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

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

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

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

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

PDE'S

Finite Difference Method



EIGEN VALUES

$\lambda = \text{Eigen Value}$

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

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

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

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

$$\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$x_1 + x_2 = 0 \Rightarrow x_1 = -x_2$$

$$x_1 + x_2 = 0 \Rightarrow x_1 = -x_2$$

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

$$-x_1 + x_2 = 0 \Rightarrow x_1 = x_2$$

$$x_1 + -1x_2 = 0 \Rightarrow x_1 = x_2$$

RIGHT BOUNDARY BC

Top boundary: $T = T_0$

Bottom boundary: $T = T_1$

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Right boundary: $\frac{\partial T}{\partial x} = 0 \Rightarrow T_{i+1} - T_i = 0$

LEFT BOUNDARY BC

Top boundary: $T = T_0$

Bottom boundary: $T = T_1$

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Left boundary: $\frac{\partial T}{\partial x} = 0 \Rightarrow T_i - T_{i-1} = 0$

TOP BOUNDARY BC

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Top boundary: $T = T_0$

BOTTOM BOUNDARY BC

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Bottom boundary: $T = T_1$

5th row of a matrix

Central difference: $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1} - 2T_i + T_{i-1}}{\Delta x^2}$

Boundary conditions: $T_{i+1} = T_0, T_{i-1} = T_1$

[A] MATRIX:

Central: $-T_{i-1} + 2T_i - T_{i+1} = -2\Delta x^2 \ddot{T}_i$

Top: $-T_{i-1} + 9T_i - 7T_{i+1} = -2\Delta x^2 \ddot{T}_i$

Bottom: $-7T_{i-1} + 9T_i - T_{i+1} = -2\Delta x^2 \ddot{T}_i$

FINITE DIFFS:

Centered finite-diff: $f(x) = \frac{f(x+\Delta x) - f(x-\Delta x)}{2\Delta x}$

Second order: $f(x) = \frac{f(x+\Delta x) - 2f(x) + f(x-\Delta x))}{(\Delta x)^2}$

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**James J. (Jong Hyuk) Park, Han-Chieh
Chao, Hamid Arabnia, Neil Y. Yen**

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Domain Decomposition Methods in Science and Engineering XIX Yunqing Huang, Ralf Kornhuber, Olof Widlund, Jinchao Xu, 2010-10-27 These are the proceedings of the 19th international conference on domain decomposition methods in science and engineering Domain decomposition methods are iterative methods for solving the often very large linear or nonlinear systems of algebraic equations that arise in various problems in mathematics computational science engineering and industry They are designed for massively parallel computers and take the memory hierarchy of such systems into account This is essential for approaching peak floating point performance There is an increasingly well developed theory which is having a direct impact on the development and improvement of these algorithms Advanced Multimedia and Ubiquitous Engineering James J. (Jong Hyuk) Park, Han-Chieh Chao, Hamid Arabnia, Neil Y. Yen, 2015-05-26 This volume brings together contributions representing the state of the art in new multimedia and future technology information research currently a major topic in computer science and electronic engineering Researchers aim to interoperate multimedia frameworks transforming the way people work and interact with multimedia data This book covers future information technology topics including digital and multimedia convergence ubiquitous and pervasive computing intelligent computing and applications embedded systems mobile and wireless communications bio inspired computing grid and cloud computing semantic web human centric computing and social networks adaptive and context aware computing security and trust computing and related areas Representing the combined proceedings of the 9th International Conference on Multimedia and Ubiquitous Engineering MUE 15 and the 10th International Conference on Future Information Technology Future Tech 2015 this book aims to provide a complete coverage of the areas outlined and to bring together researchers from academic and industry and other practitioners to share their research ideas challenges and solutions Parallel Processing and Applied Mathematics Roman Wyrzykowski, Jack Dongarra, Marcin Paprzycki, Jerzy Wasniewski, 2003-08-01 This book constitutes the thoroughly refereed post proceedings of the 4th International Conference on Parallel Processing and Applied Mathematics PPAM 2002 held in Naleczow Poland in September 2001 The 101 papers presented were carefully reviewed and improved during two rounds of reviewing and revision The book offers topical sections on distributed and grid architectures scheduling and load balancing performance analysis and prediction parallel non numerical algorithms parallel programming tools and environments parallel numerical algorithms applications and evolutionary computing and neural networks **Domain Decomposition Methods in Science and Engineering XX** Randolph Bank, Michael Holst, Olof Widlund, Jinchao Xu, 2013-07-03 These are the proceedings of the 20th international conference on domain decomposition methods in science and engineering Domain decomposition methods are iterative methods for solving the often very large linear or nonlinear systems of algebraic equations that arise when various problems in continuum mechanics are discretized using finite elements They are designed for massively parallel computers and take the memory hierarchy of such systems in mind This is

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Lecture Notes on Numerical Methods in Engineering and Sciences, 2009
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