

NUMERICAL METHODS

C / RAPPY EXAM 12 / 11/19 / 2022 [20.00]

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:

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

STANDARD DEVIATION:

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

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

INTERPOLATION

Order	Degree	Nodes	Equation
1	0	2	$P_0(x) = a_0 + a_1 x$
2	1	3	$P_1(x) = a_0 + a_1 x + a_2 x^2$
3	2	4	$P_2(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$
4	3	5	$P_3(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4$

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:

$$y_{i+1} = y_i + \Delta x \frac{1}{6} (k_1 + 4k_2 + k_3 + k_4)$$

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

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

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

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

POLYNOMIAL QUADRATIC REGRESSION:



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

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

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

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

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

EIGEN VALUES

2x2 Matrix:

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

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

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

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

3x3 Matrix:

$$\det \begin{bmatrix} a-\lambda & b & c \\ d & e-\lambda & f \\ g & h & i-\lambda \end{bmatrix} = 0$$

PDE'S

FINITE DIFFERENCE METHOD:



Central Difference:

$$u_{i,j} = \frac{1}{4} (u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1}) + \frac{\Delta x^2}{12} u_{xxxx}$$

Right Boundary BC:

$$u_x = 0 \Rightarrow u_{i,j} = u_{i+1,j}$$

Left Boundary BC:

$$u_x = 0 \Rightarrow u_{i,j} = u_{i-1,j}$$

HEAT CONDUCTION:



5th Row of A Matrix:

$$[0 \quad -1 \quad 0 \quad -1 \quad 4 \quad -1 \quad 0 \quad -1 \quad 0] u = 0$$

Right Boundary BC:

$$u_x = 0 \Rightarrow u_{i,j} = u_{i+1,j}$$

Left Boundary BC:

$$u_x = 0 \Rightarrow u_{i,j} = u_{i-1,j}$$

[A] MATRIX:

$$u_{i,j} = \frac{1}{4} (u_{i+1,j} + u_{i-1,j} + u_{i,j+1} + u_{i,j-1}) + \frac{\Delta x^2}{12} u_{xxxx}$$

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

TRUNCATION ERROR:

$$T.E. = \frac{f(x_{i+1}) - f(x_i)}{\Delta x} - f'(x_i)$$

$$f(x) = f(x_i) + f'(x_i)(x - x_i) + \frac{f''(x_i)}{2!}(x - x_i)^2 + \dots$$

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Wen Shen



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Table of Contents Numerical Methods Lecture Notes 01 Vsb

1. Understanding the eBook Numerical Methods Lecture Notes 01 Vsb
 - The Rise of Digital Reading Numerical Methods Lecture Notes 01 Vsb
 - Advantages of eBooks Over Traditional Books
2. Identifying Numerical Methods Lecture Notes 01 Vsb
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Numerical Methods Lecture Notes 01 Vsb
 - User-Friendly Interface
4. Exploring eBook Recommendations from Numerical Methods Lecture Notes 01 Vsb
 - Personalized Recommendations
 - Numerical Methods Lecture Notes 01 Vsb User Reviews and Ratings
 - Numerical Methods Lecture Notes 01 Vsb and Bestseller Lists

5. Accessing Numerical Methods Lecture Notes 01 Vsb Free and Paid eBooks
 - Numerical Methods Lecture Notes 01 Vsb Public Domain eBooks
 - Numerical Methods Lecture Notes 01 Vsb eBook Subscription Services
 - Numerical Methods Lecture Notes 01 Vsb Budget-Friendly Options
6. Navigating Numerical Methods Lecture Notes 01 Vsb eBook Formats
 - ePub, PDF, MOBI, and More
 - Numerical Methods Lecture Notes 01 Vsb Compatibility with Devices
 - Numerical Methods Lecture Notes 01 Vsb Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Numerical Methods Lecture Notes 01 Vsb
 - Highlighting and Note-Taking Numerical Methods Lecture Notes 01 Vsb
 - Interactive Elements Numerical Methods Lecture Notes 01 Vsb
8. Staying Engaged with Numerical Methods Lecture Notes 01 Vsb
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Numerical Methods Lecture Notes 01 Vsb
9. Balancing eBooks and Physical Books Numerical Methods Lecture Notes 01 Vsb
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Numerical Methods Lecture Notes 01 Vsb
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Numerical Methods Lecture Notes 01 Vsb
 - Setting Reading Goals Numerical Methods Lecture Notes 01 Vsb
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Numerical Methods Lecture Notes 01 Vsb
 - Fact-Checking eBook Content of Numerical Methods Lecture Notes 01 Vsb
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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